

Title: the modern POWER SUPPLY AND BATTERY CHARGER CIRCUIT encyclopedia

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1. Battery Chargers and Zappers
2. Power Supplies - Fixed
3. Power Supplies - High Voltage
4. Power Supplies - Variable
5. Power Supply Monitors
6. Power Supply Protection Circuits

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* ngpn = no given page number

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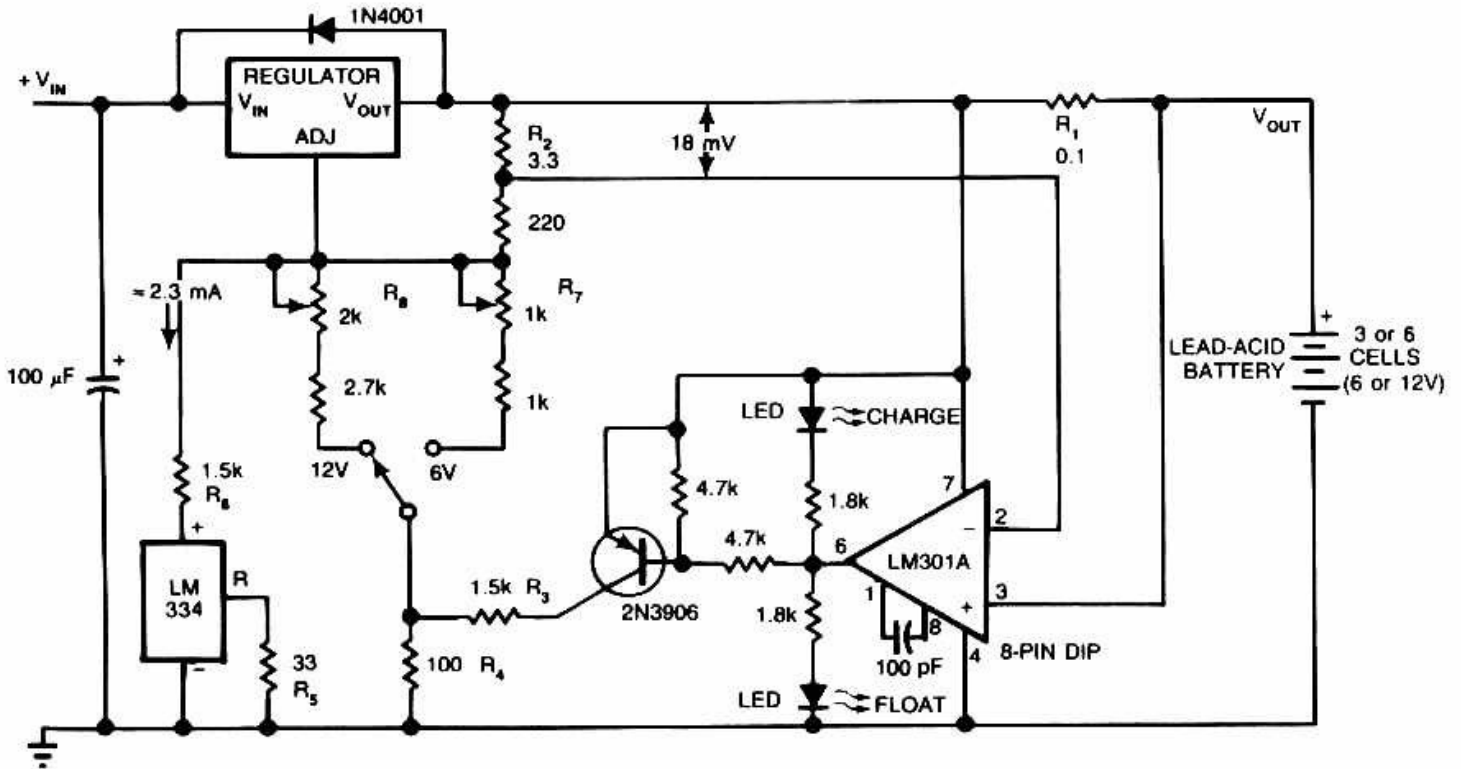
Battery Chargers and Zappers

The sources of the following circuits are contained in the Sources section, which begins on page 125. The figure number in the box of each circuit correlates to the source entry in the Sources section.

Lead-Acid Battery Charger
12-V Battery Charger
200-mA-hour 12-V NiCad Battery Charger
NiCad Charger with Current and Voltage Limiting
14-V 4-A Battery Charger/Power Supply
Fast Charger for NiCad Batteries
Current-Limited 6-V Charger
NiCad Charger
Simple NiCad Battery Zapper
Battery Charger
Automatic Shutoff Battery Charger
Battery-Charging Regulator
12-V Battery-Charger Control (20 rms Max.)
Battery Charger
Universal Battery Charger
Lead-Acid Low-Battery Detector

Universal Battery Charger
UJT Battery Charger
Automotive Charger for NiCad Battery Packs
Constant-Voltage Current-Limited Charger
Versatile Battery Charger
Gel-Cell Charger
NiCad Battery Zapper
PUT Battery Charger
Thermally Controlled NiCad Charger
NiCad Battery Zapper II
Portable NiCad Battery Charger
Lithium Battery Charger
Rapid Battery Charger for Icom IC-2A
Battery Charger Operates on Single Solar Cell
Wind-Powered Battery Charger

LEAD-ACID BATTERY CHARGER



EDN

Fig. 1-1

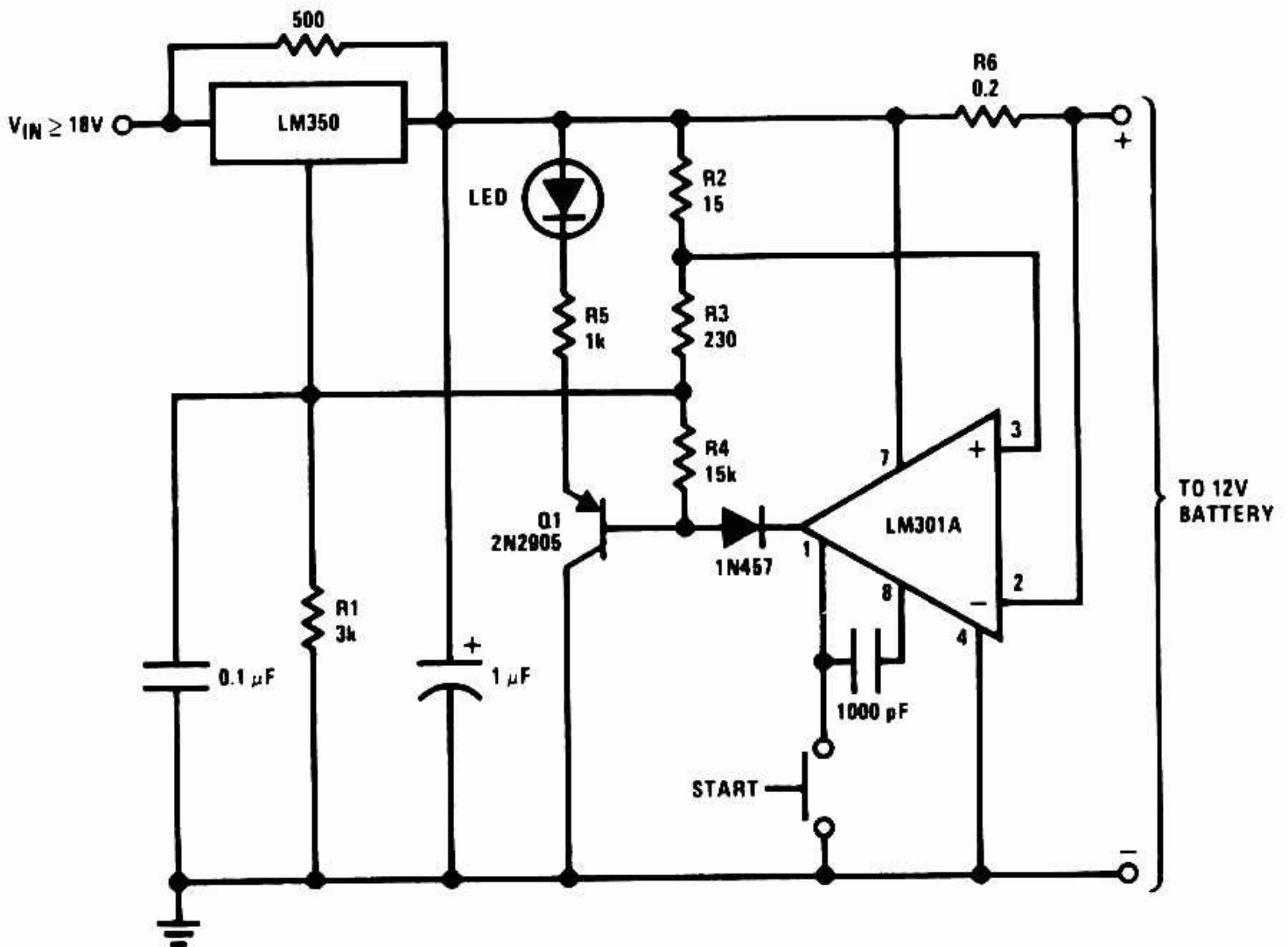
This circuit furnishes an initial voltage of 2.5 V per cell at 25°C to rapidly charge a battery. The charging current decreases as the battery charges, and when the current drops to 180 mA, the charging circuit reduces the output voltage to 2.35 V per cell, leaving the battery in a fully charged state. This lower voltage prevents the battery from overcharging, which would shorten its life.

The LM301A compares the voltage drop across R1 with an 18 mV reference set by R2. The comparator's output controls the voltage regulator, forcing it to produce the lower float voltage when the battery-charging current, passing through R1, drops below 180 mA. The 150 mV difference between the charge and float voltages is set by the ratio of R3 to R4. The LEDs show the state of the circuit.

Temperature compensation helps prevent overcharging, particularly when a battery undergoes wide temperature changes while being charged. The LM334 temperature sensor should be placed near or on the battery to decrease the charging voltage by 4 mV/°C for each cell. Because batteries need more temperature compensation at lower temperatures, change R5 to 30 Ω for a tc of -5 mV/°C per cell if application will see temperatures below -20°C.

The charger's input voltage must be filtered dc that is at least 3 V higher than the maximum required output voltage: approximately 2.5 V per cell. Choose a regulator for the maximum current needed: LM371 for 2 A, LM350 for 4 A, or LM338 for 8 A. At 25°C and with no output load, adjust R7 for a V_{OUT} of 7.05 V, and adjust R8 for a V_{OUT} of 14.1 V.

12-V BATTERY CHARGER

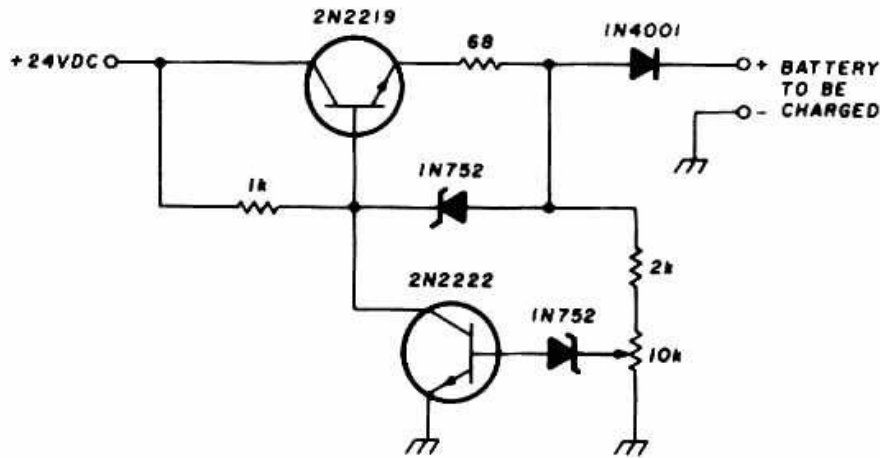


NATIONAL SEMICONDUCTOR

Fig. 1-2

This circuit is a high-performance charger for gelled-electrolyte lead-acid batteries. This charger quickly recharges the battery and shuts off at full charge. Initially, charging current is limited to 2 A. As the battery voltage rises, current to the battery decreases, and when the current has decreased to 150 mA, the charger switches to a lower float voltage, which prevents overcharge. When the start switch is pushed, the output of the charger goes to 14.5 V. As the battery approaches full charge, the charging current decreases and the output voltage is reduced from 14.5 V to about 12.5 V, terminating the charging. Transistor Q1 then lights the LED as a visual indication of full charge.

200-mA/HOUR, 12-V NICAD BATTERY CHARGER

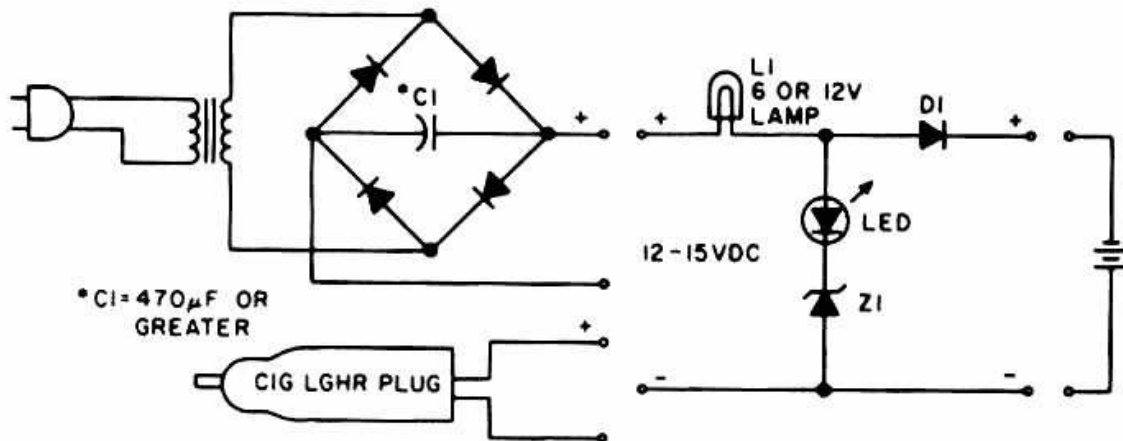


HAM RADIO

Fig. 1-3

This circuit charges the battery at 75 mA until the battery is charged, then it reduces the current to a trickle rate. It will completely recharge a dead battery in four hours and the battery can be left in the charger indefinitely. To set the shut-off point, connect a 270- Ω , 2-W resistor across the charge terminals and adjust the pot for 15.5 V across the resistor.

NICAD CHARGER WITH CURRENT AND VOLTAGE LIMITING

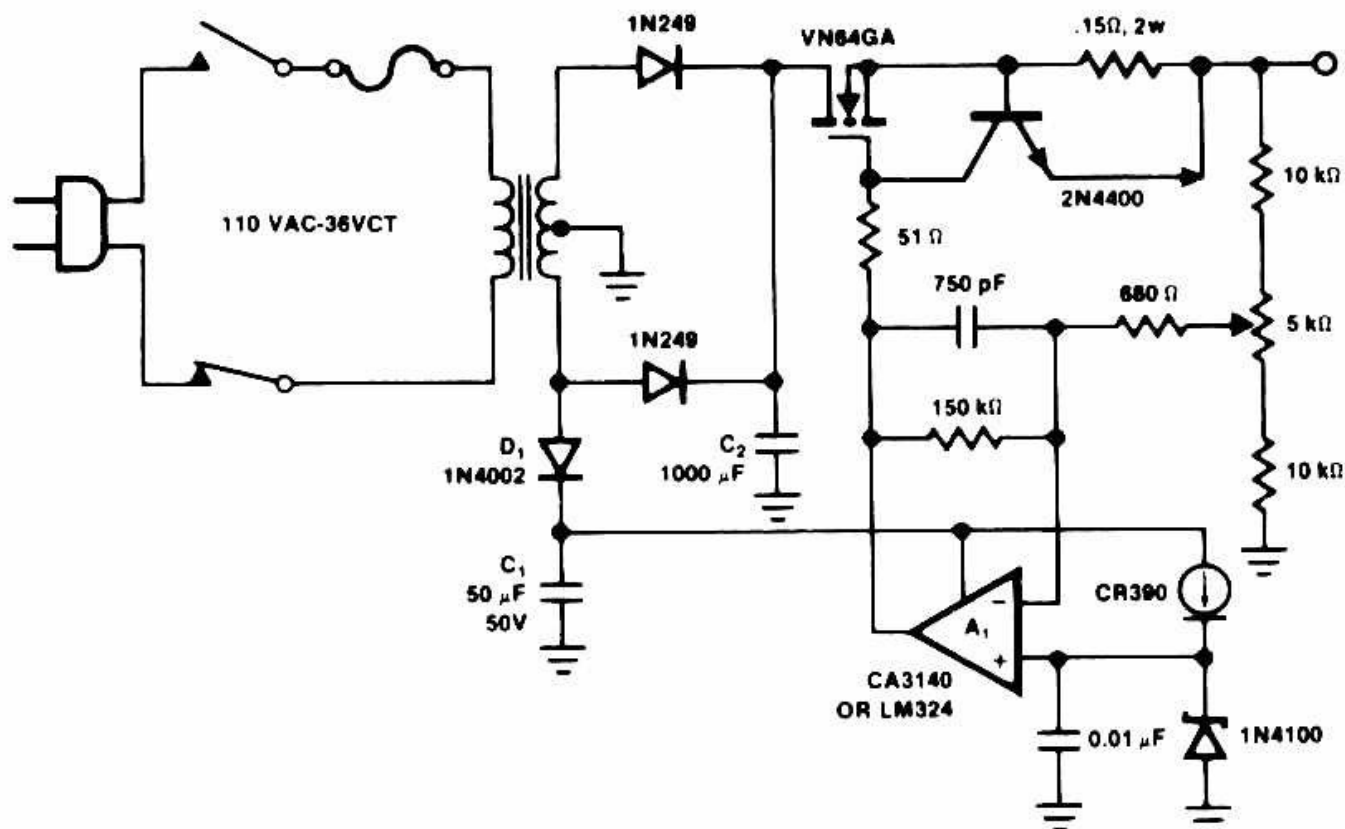


73 AMATEUR RADIO

Fig. 1-4

Lamp L1 will glow brightly and the LED will be out when the battery is low and being charged, but the LED will be bright and the light dim when the battery is almost ready. L1 should be a bulb that is rated for the current you want (usually the battery capacity divided by 10). Diode D1 should be at least 1 A, and Z1 is a 1-W zener diode with a voltage determined by the full-charge battery voltage minus 1.5 V. After the battery is fully charged, the circuit will float it at about battery capacity divided by 100 mA.

14-V 4-A BATTERY CHARGER/POWER SUPPLY

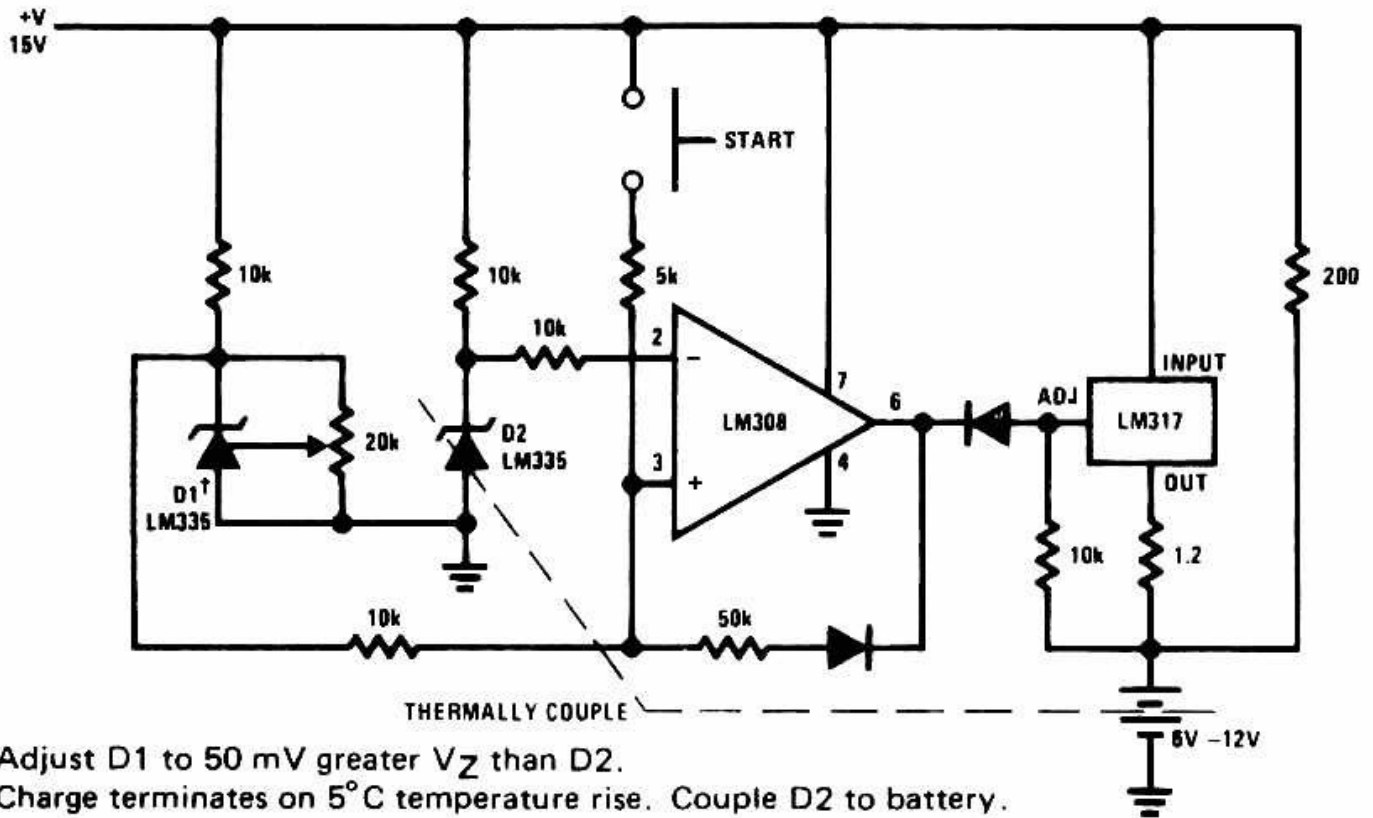


SILICONIX

Fig. 1-5

Operational amplifier A1 directly drives the VN64GA with the error signal to control the output voltage. Peak rectifier D1, C1 supplies error amplifier A1 and the reference zener. This extra drive voltage must exceed its source voltage by several volts for the VN64GA to pass full load current. The output voltage is pulsating dc, which is quite satisfactory for battery charging. To convert the system to a regulated dc supply, capacitor C2 is increased and another electrolytic capacitor is added across the load. The response time is very fast, determined by the op amp. The 2N4400 current-limiter circuit prevents the output current from exceeding 4.5 A. However, maintaining a shorted condition for more than one second will cause the VN64GA to exceed its temperature ratings. A generous heatsink, on the order of 1°C/W, must be used.

FAST CHARGER FOR NICAD BATTERIES

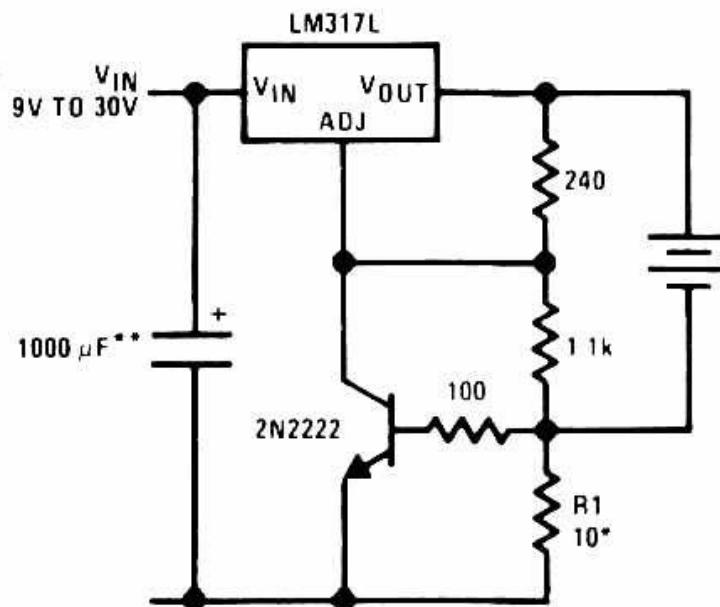


Adjust D1 to 50 mV greater V_Z than D2.
 Charge terminates on 5°C temperature rise. Couple D2 to battery.

NATIONAL SEMICONDUCTOR

Fig. 1-6

CURRENT-LIMITED 6-V CHARGER

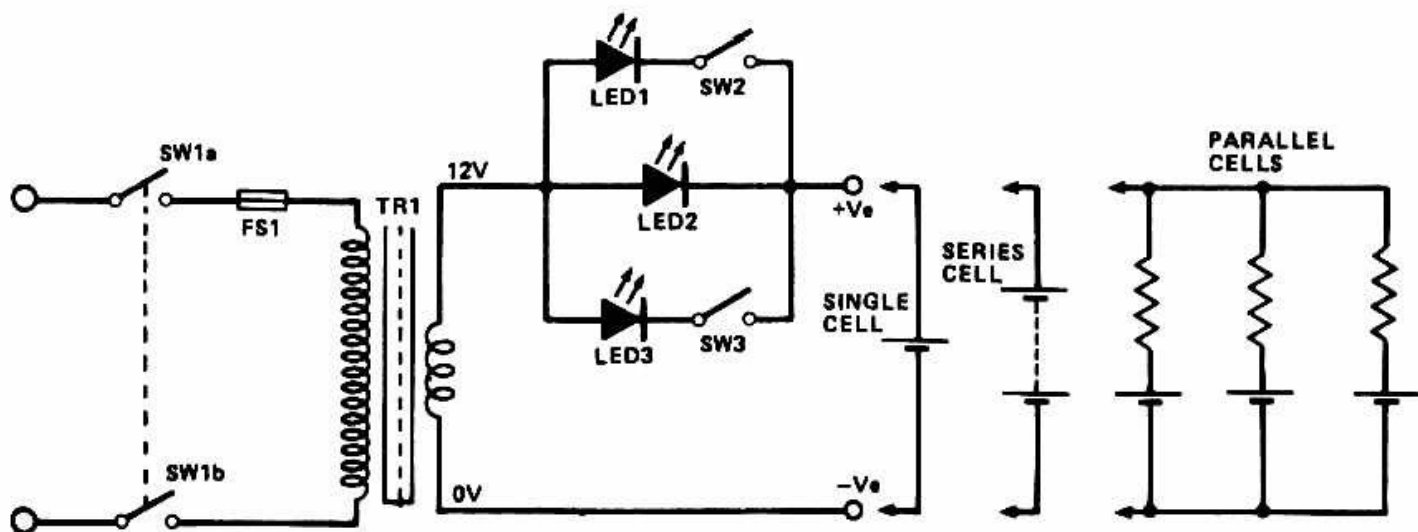


* Sets peak current, $I_{PEAK} = 0.6V/R1$
 ** 1000 μF is recommended to filter out any input transients

NATIONAL SEMICONDUCTOR

Fig. 1-7

NICAD CHARGER

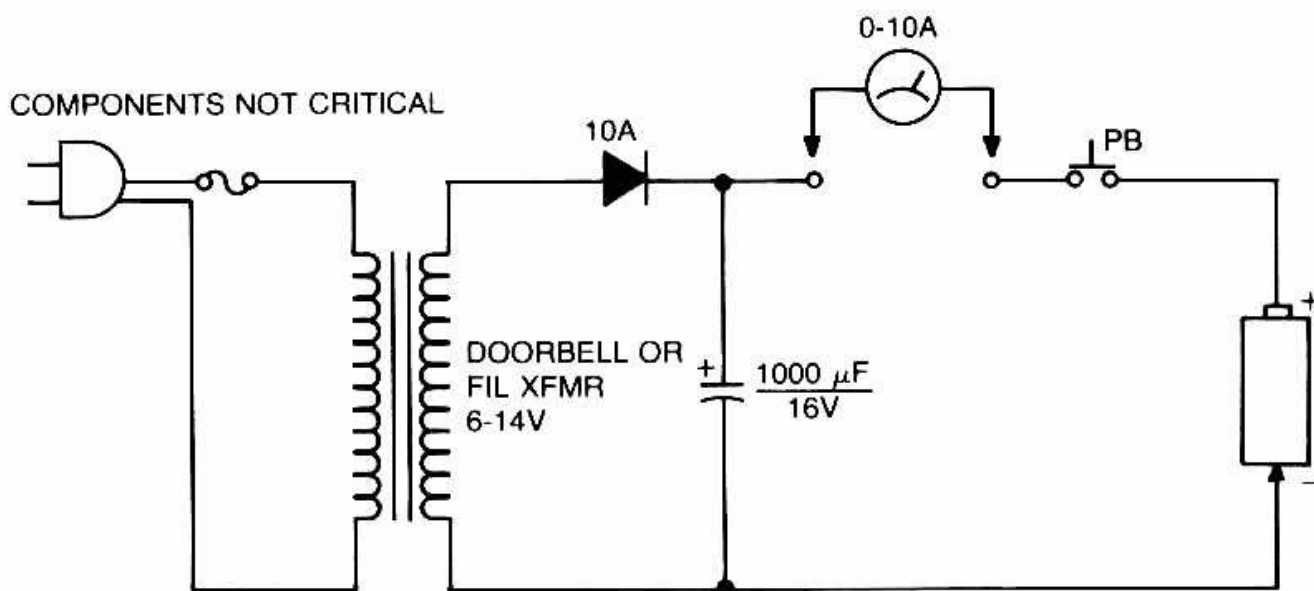


ELECTRONICS TODAY INTERNATIONAL

Fig. 1-8

This circuit uses constant current LEDs to adjust charging current. It uses LEDs that pass a constant current of about 15 mA for an applied voltage range of 2 to 18 V. They can be paralleled to give any multiple of 15 mA and they light up when current is flowing. The circuit will charge a single cell at 15, 30, or 45 mA, or cells in series up to the rated supply voltage limit (about 14 V).

SIMPLE NICAD BATTERY ZAPPER

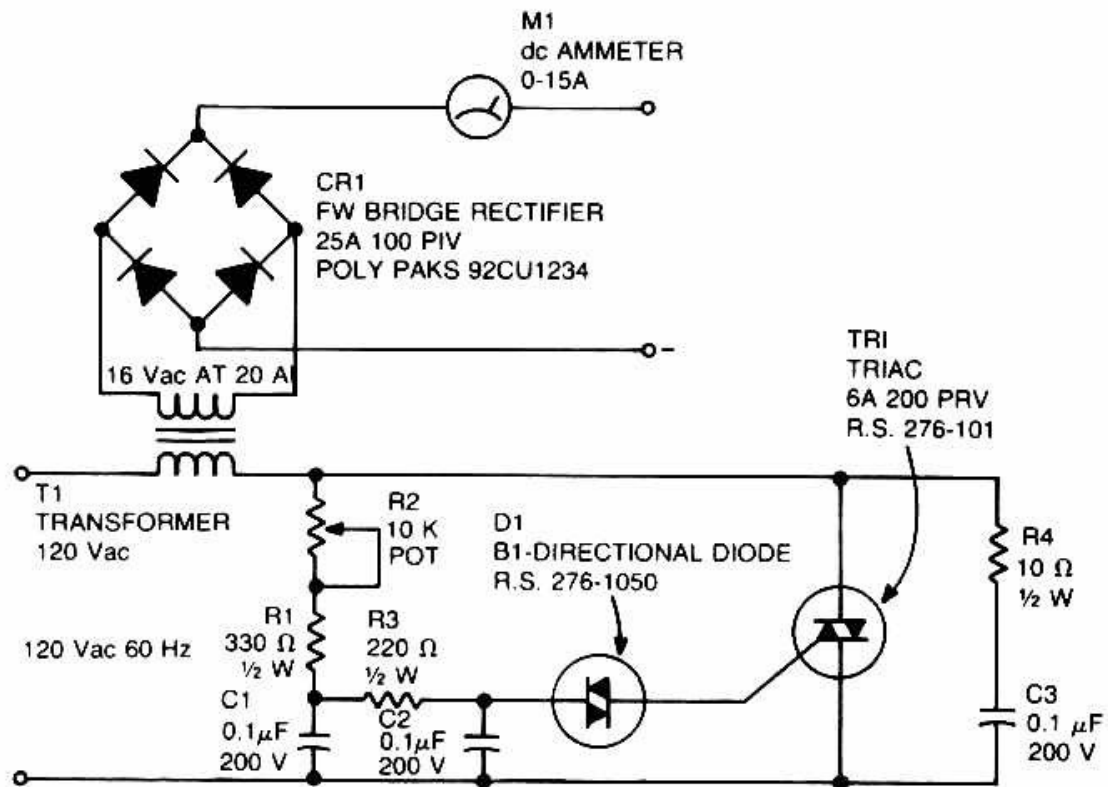


73 AMATEUR RADIO

Fig. 1-9

This circuit is used to clear internal shorts in nickel-cadmium batteries. To operate, connect a NiCad battery to the output and press the pushbutton for three seconds.

BATTERY CHARGER

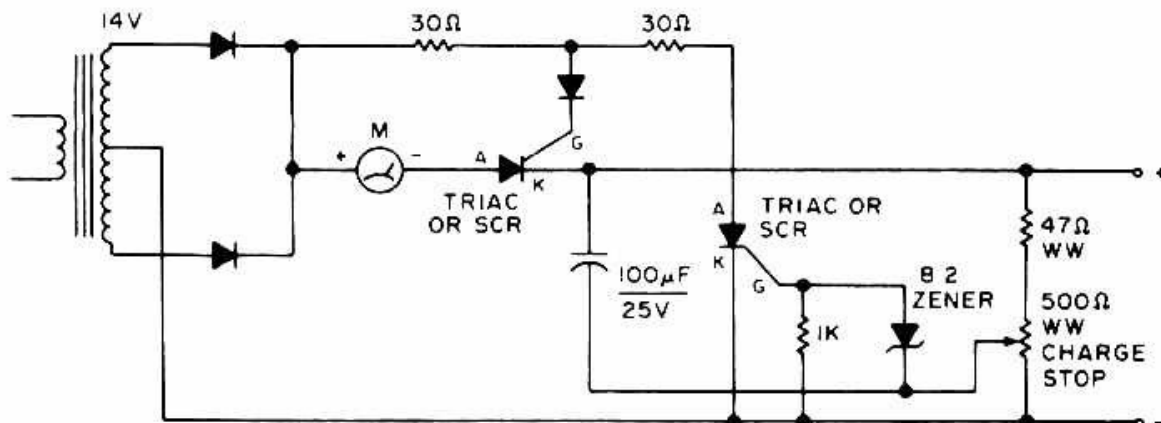


73 AMATEUR RADIO

Fig. 1-10

A diac is used in the gate circuit to provide a threshold level for firing the triac. C3 and R4 provide a transient suppression network. R1, R2, R3, C1, and C2 provide a phase-shift network for the signal being applied to the gate. R1 is selected to limit the maximum charging current at full rotation of R2.

AUTOMATIC SHUTOFF BATTERY CHARGER

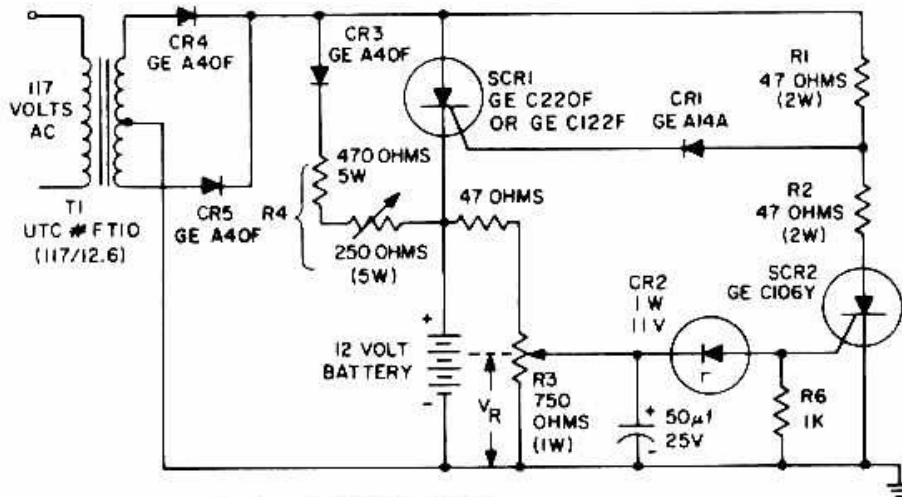


73 AMATEUR RADIO

Fig. 1-11

Adjust this circuit by setting the 500-Ω resistor while it is attached to a fully charged battery.

BATTERY-CHARGING REGULATOR

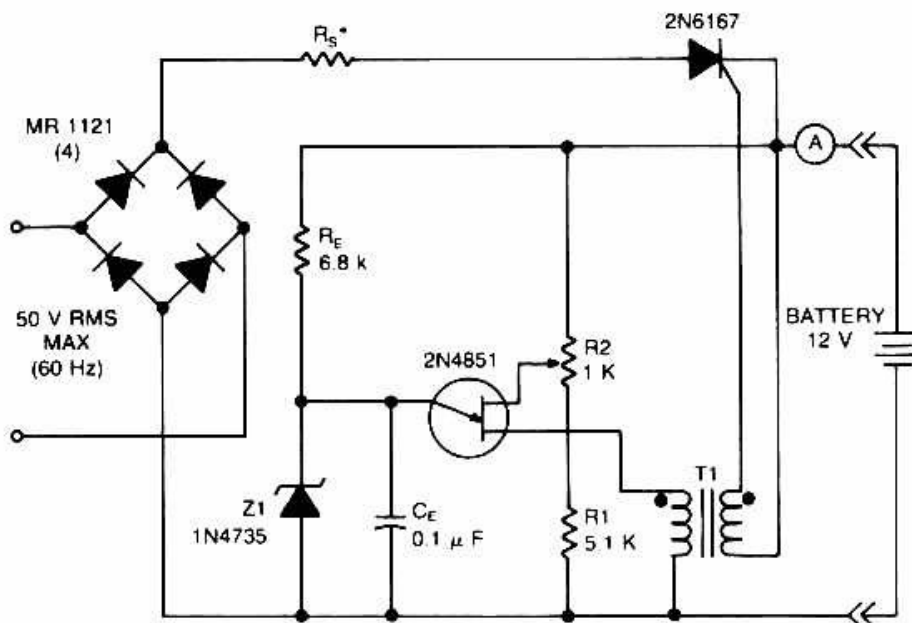


ALL RESISTORS 1/2 WATT EXCEPT AS NOTED

Fig. 1-12

The circuit is capable of charging a 12-V battery at up to a six ampere rate. Other voltages and currents, from 6 to 600 V and up to 300 A, can be accommodated by suitable component selection. When the battery voltage reaches its fully charged level, the charging SCR shuts off, and a trickle charge, as determined by the value of R4, continues to flow.

12-V BATTERY-CHARGER CONTROL (20 A rms MAX.)

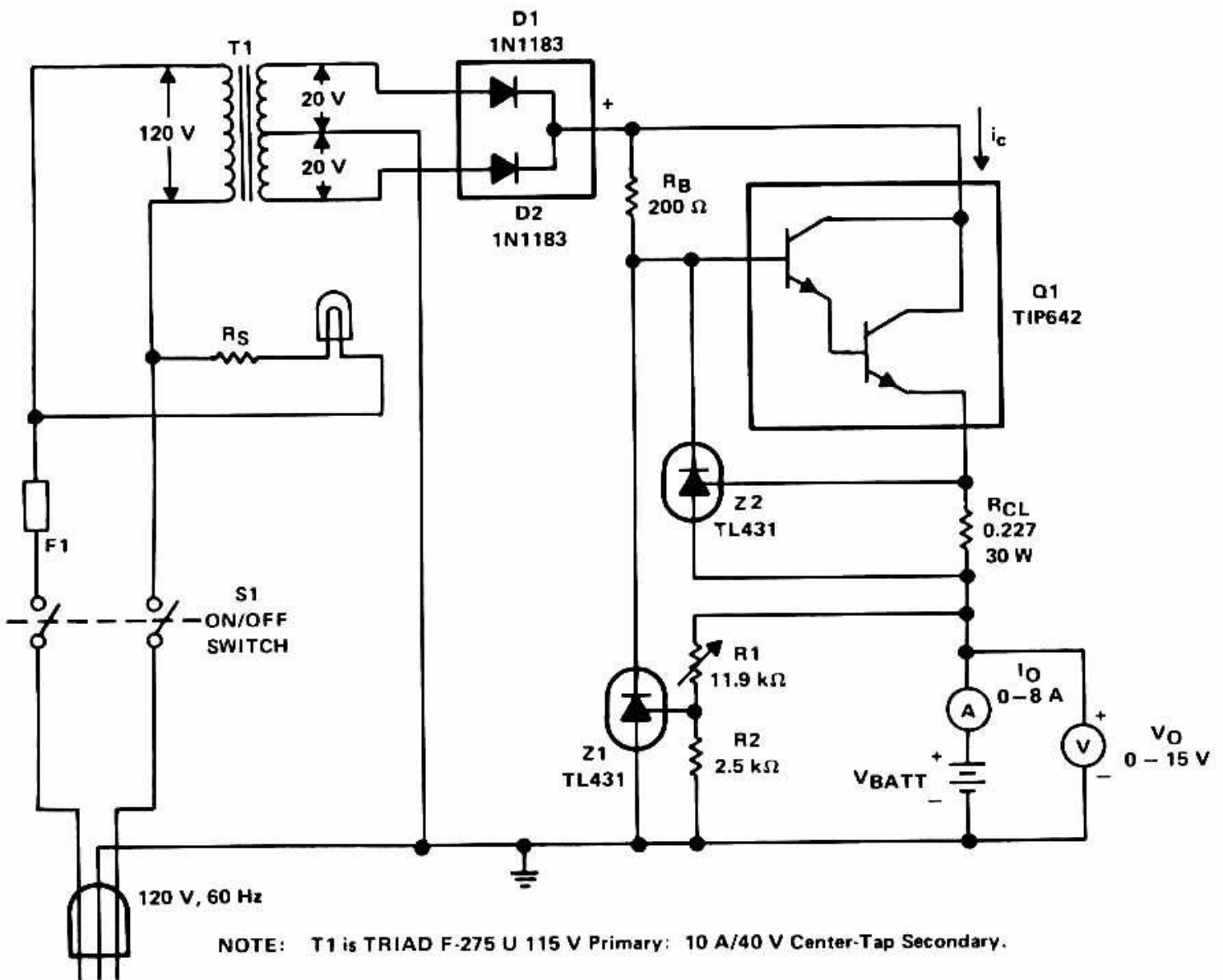


T1 - PRIMARY = 30 TURNS #22
 SECONDARY = 45 TURNS #22
 CORE = FERROXCUBE 203 F 181-3C3
 R_s - SERIES RESISTANCE TO LIMIT CURRENT THROUGH SCR.
 2N6167 IS RATED AT 20 AMPS RMS

MOTOROLA

Fig. 1-13

BATTERY CHARGER

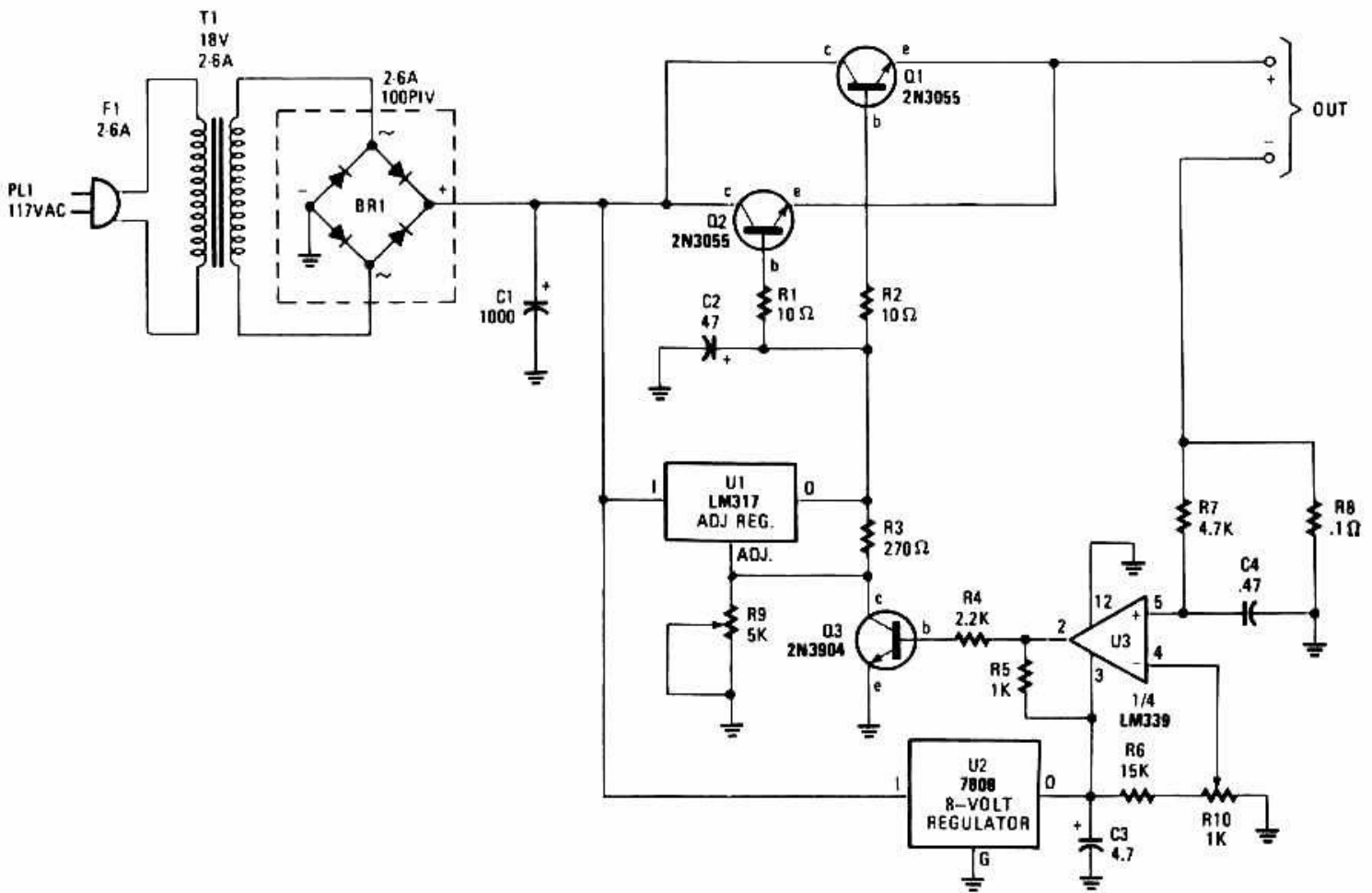


TEXAS INSTRUMENTS

Fig. 1-14

The charger is based on a charging voltage of 2.4 V per cell, in accordance with most manufacturers' recommendations. The circuit pulses the battery under charge with 14.4 V (6 cells \times 2.4 V per cell) at a rate of 120 Hz. The design provides current limiting to protect the charger's internal components while limiting the charging rate to prevent damaging severely discharged lead-acid batteries. The maximum recommended charging current is normally about one-fourth the ampere-hour rating of the battery. For example, the maximum charging current for an average 44 ampere-hour battery is 11 A. If the impedance of the load requires a charging current greater than the 11 A current limit, the circuit will go into current limiting. The amplitude of the charging pulses is controlled to maintain a maximum peak charging current of 11 A (8 A average).

UNIVERSAL BATTERY CHARGER



POPULAR ELECTRONICS

Fig. 1-15

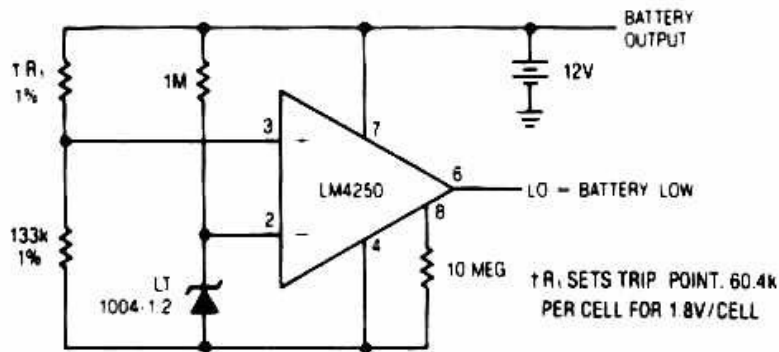
The charger's output voltage is adjustable and regulated, and has an adjustable constant-current charging circuit that makes it easy to use with most NiCad batteries. The charger can charge a single cell or a number of series-connected cells up to a maximum of 18 V.

Power transistors Q1 and Q2 are connected as series regulators to control the battery charger's output voltage and charge-current rate. An LM317 adjustable voltage regulator supplies the drive signal to the bases of power transistors Q1 and Q2. Potentiometer R9 sets the output-voltage level. A current-sampling resistor, R8 (a 0.1- Ω , 5-W unit), is connected between the negative output lead and circuit ground. For each amp of charging current that flows through R8, a 100 mV output is developed across it. The voltage developed across R8 is fed to one input of comparator U3. The other input of the comparator is connected to variable resistor R10.

As the charging voltage across the battery begins to drop, the current through R8 decreases. Then the voltage feeding pin 5 of U3 decreases, and the comparator output follows, turning Q3 back off, which completes the signal's circular path to regulate the battery's charging current.

The charging current can be set by adjusting R10 for the desired current. The circuit's output voltage is set by R9.

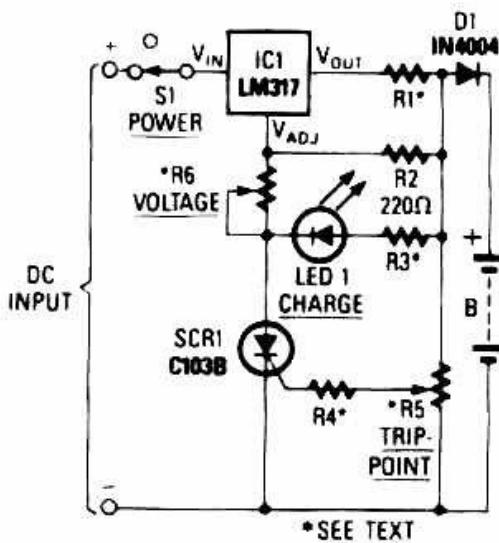
LEAD-ACID LOW-BATTERY DETECTOR



LINEAR TECHNOLOGY

Fig. 1-16

UNIVERSAL BATTERY CHARGER

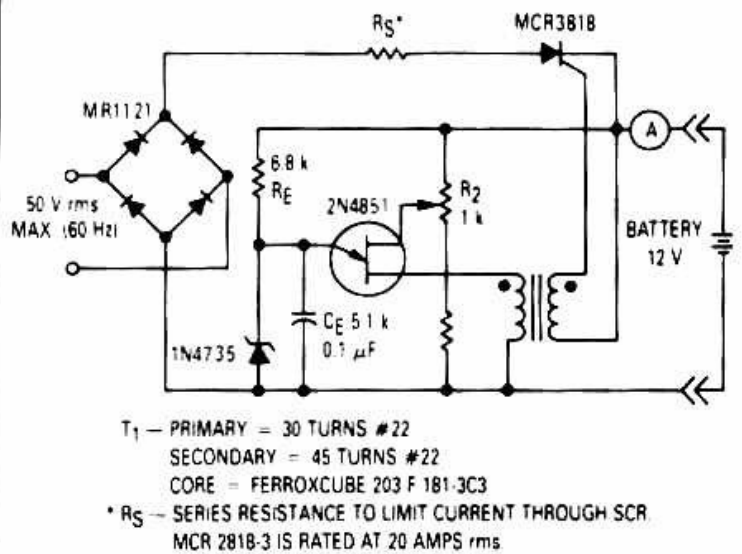


RADIO-ELECTRONICS

Fig. 1-17

When power is applied to the circuit, SCR1 is off, so there is no bias-current path to ground; thus, LM317 acts as a current regulator. The LM317 is connected to the battery through steering diode D1, limiting resistor R1, and bias resistor R2. The steering diode prevents the battery from discharging through the LED and the SCR when power is removed from the circuit. As the battery charges, the voltage across trip-point potentiometer R5 rises, and at some point, turns on the SCR. Then, current from the regulator can flow to ground, so the regulator now functions in the voltage mode. When the SCR turns on, it also provides LED1 with a path to ground through R3. So, when LED1 is on, the circuit is in the voltage-regulating mode; when LED1 is off, the circuit is in the current-regulating mode.

UJT BATTERY CHARGER

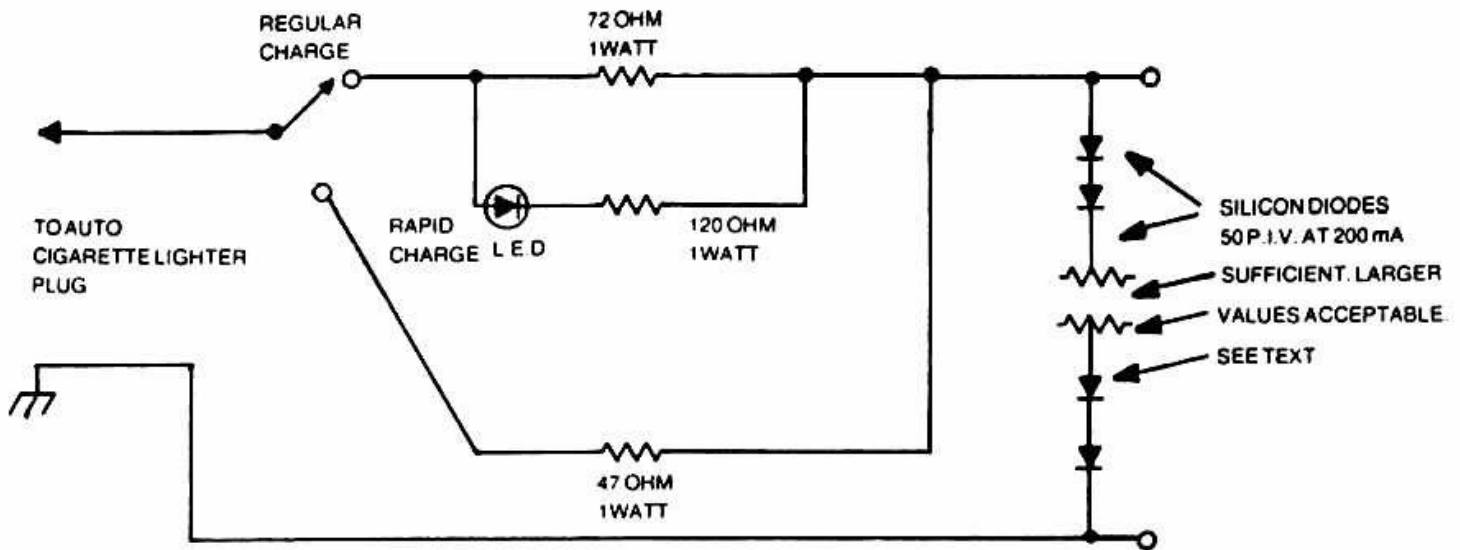


MOTOROLA

Fig. 1-18

This circuit will not work unless the battery to be charged is connected with proper polarity. The battery voltage controls the charger and when the battery is fully charged, the charger will not supply current to the battery. The battery charging current is obtained through the SCR when it is triggered into the conducting state by the UJT relaxation oscillator. The oscillator is only activated when the battery voltage is low. $V_{B_2B_1}$ of the UJT is derived from the voltage of the battery to be charged, and since $V_P = V_D = V_{B_2B_1}$; the higher $V_{B_2B_1}$, the higher V_P . When V_P exceeds the breakdown voltage of the zener diode Z1, the UJT will cease to fire and the SCR will not conduct. This indicates that the battery has attained its desired charge as set by R2.

AUTOMOTIVE CHARGER FOR NICAD BATTERY PACKS



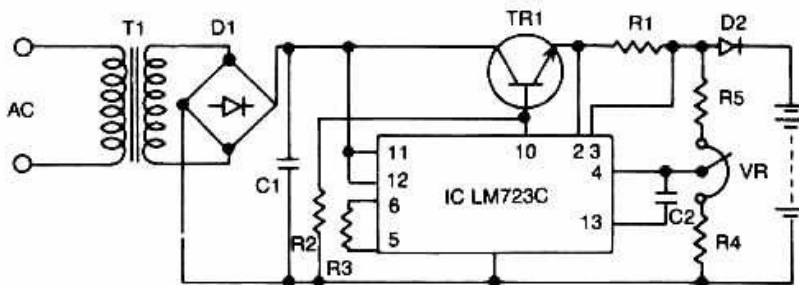
TAB BOOKS

Fig. 1-19

The number of silicon diodes across the output is determined by the voltage of the battery pack. Figure each diode at 0.7 V. For example, a 10.9-V pack would require $10.9/0.7 = 15.57$, or 16 diodes.

CONSTANT-VOLTAGE CURRENT-LIMITED CHARGER

IC LM723C VOLTAGE REGULATOR (FOR 12V dc OUTPUT 0.42A MAX.)



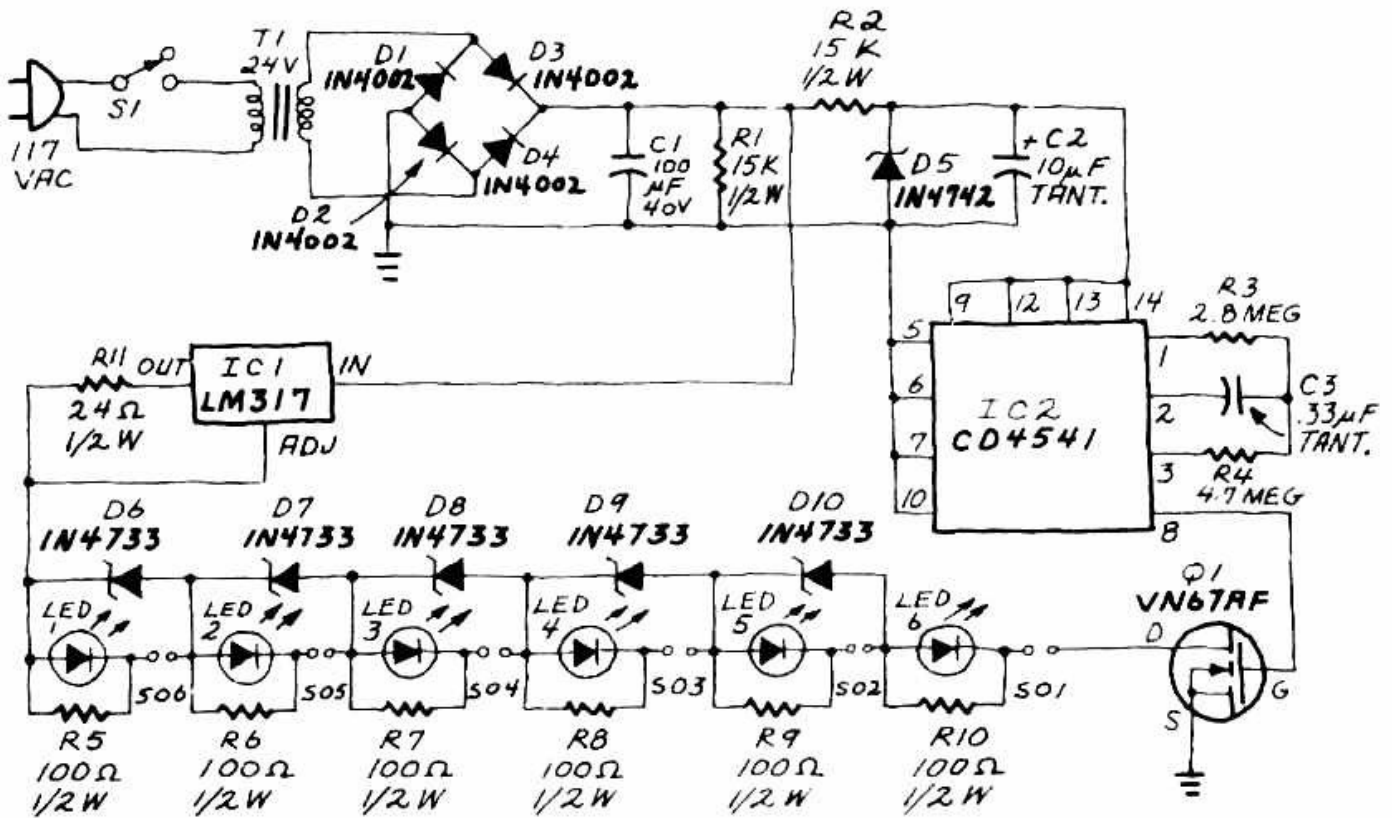
For 12-V sealed lead-acid batteries.

- T1 Transformer, dc 13V (rms), 1-3A (rms)
- D1,D2 100V 1A Diode
- C1 50V, 470µF Electrolytic Capacitor
- TR1 MJ2840 10A 60V 150W (Motorola)
- IC LM723C (National Semiconductor)
- R1 4.7 Ohm 1/2W 3P
- R2 5.1K Ohm 1/4W
- R3 3.9K Ohm 1/4W
- R4 7.5K Ohm 1/4W
- R5 8.2K Ohm 1/4W
- VR 2K Ohm
- C2 50V 1000pF

YUASA BATTERY

Fig. 1-20

VERSATILE BATTERY CHARGER



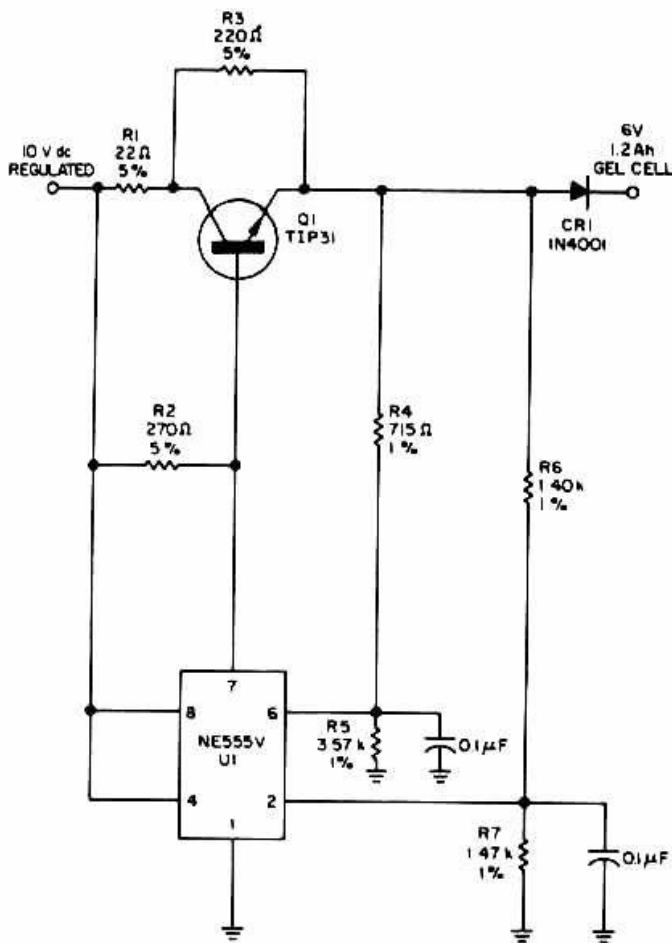
RADIO-ELECTRONICS

Fig. 1-21

An LM317 voltage regulator is configured as a constant-current source. It is used to supply the 50-mA charging current to S01-S06, an array of AA-cell battery holders. Each of the battery holders is wired in series with an LED and its associated shunt resistor. When the battery holder contains a battery, the LED glows during charging. Each battery holder/LED combination is paralleled by a 5.1-V zener diode. If the battery holder is empty, the zener conducts the current around the holder.

A timing circuit prevents overcharging. When power is applied to the circuit, timing is initiated by IC2, a CD4541 oscillator/programmable timer. The output of IC2 is fed to Q1. When that output is high, the transistor is on, and the charging circuit is completed. When the output is low, the transistor is off, and the path to ground is interrupted.

GEL-CELL CHARGER

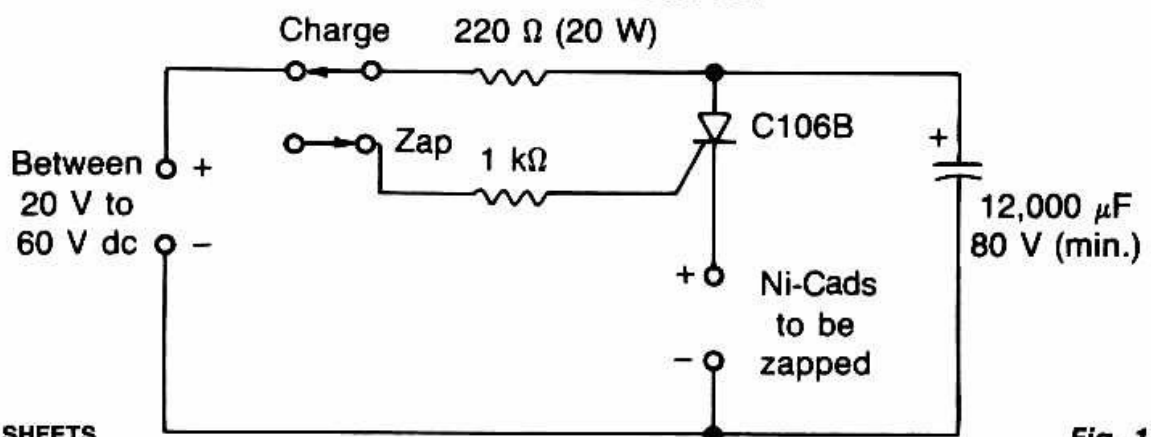


This circuit detects a full-charge state and automatically switches to a float condition—from 240 to 12 mA.

ELECTRONIC DESIGN

Fig. 1-22

NICAD BATTERY ZAPPER

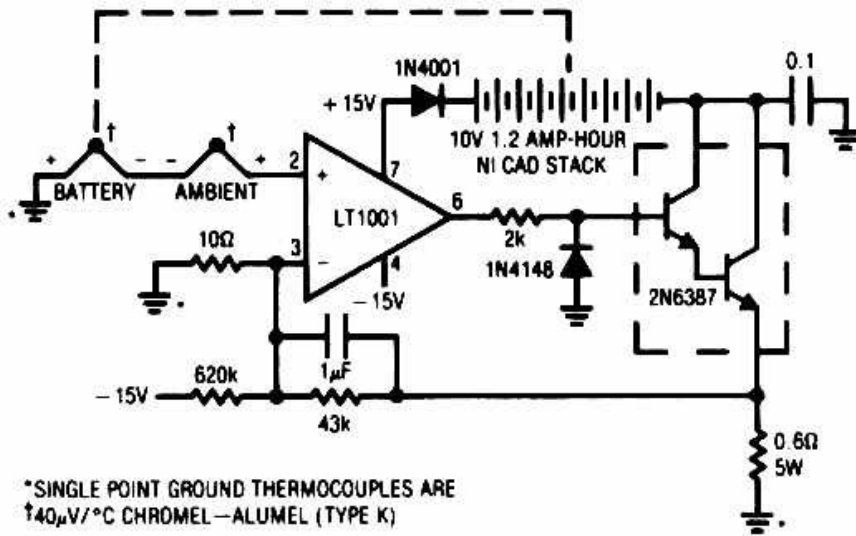


WILLIAM SHEETS

Fig. 1-23

The short in a NiCad battery can be “burned off” with this zapper. Use of the SCR keeps heavy discharge current from damaging switch contacts.

THERMALLY CONTROLLED NICAD CHARGER



LINEAR TECHNOLOGY CORP.

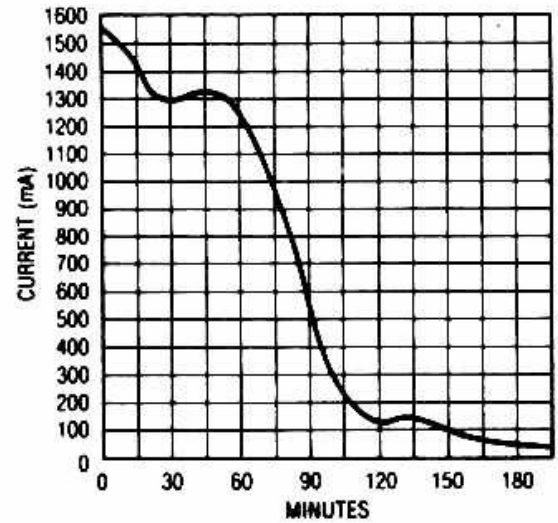
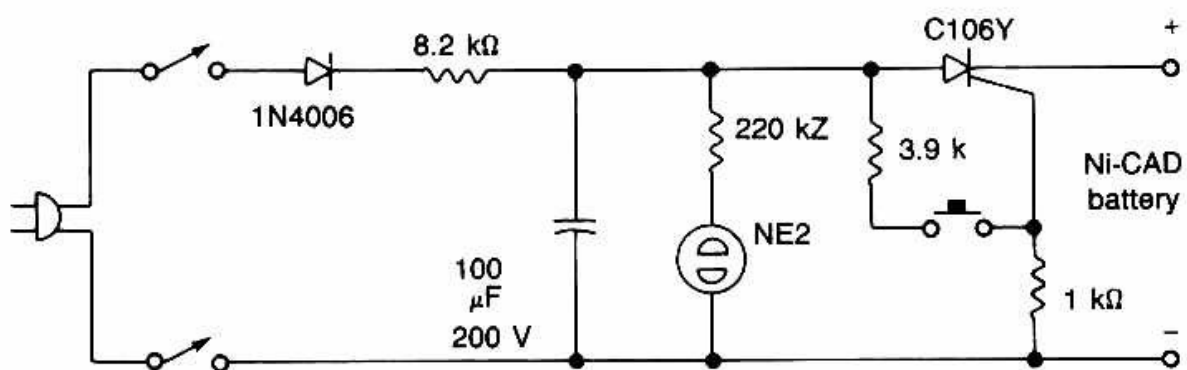


Fig. 1-24

One way to charge NiCad batteries rapidly without abuse is to measure cell temperature and taper the charge accordingly. The circuit uses a thermocouple for this function. A second thermocouple nulls out the effects of ambient temperature. The temperature difference between the two thermocouples determines the voltage, which appears at the amplifier's positive input. As battery temperature rises, this small negative voltage (1°C difference between the thermocouples equals 40 μ V) becomes larger. The amplifier, operating at a gain of 4300, gradually reduces the current through the battery to maintain its inputs at balance. The battery charges at a high rate until heating occurs and the circuit then tapers the charge. The values given in the circuit limit the battery-surface temperature rise over ambient to about 5°C.

NICAD BATTERY ZAPPER II

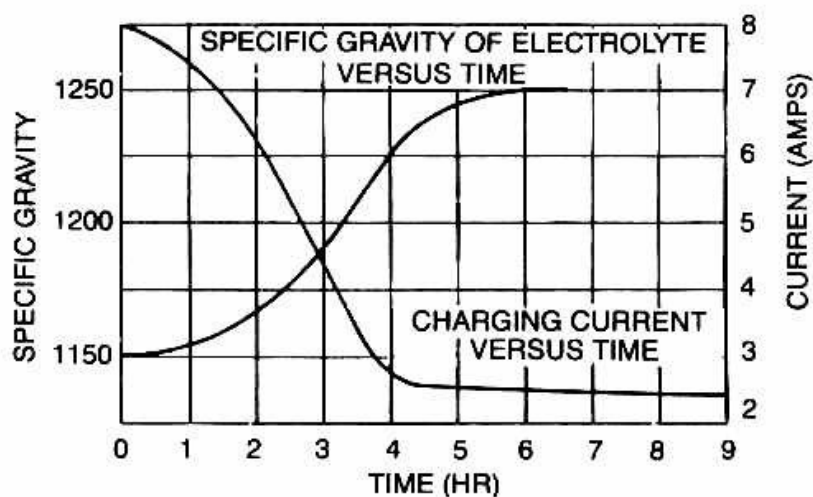
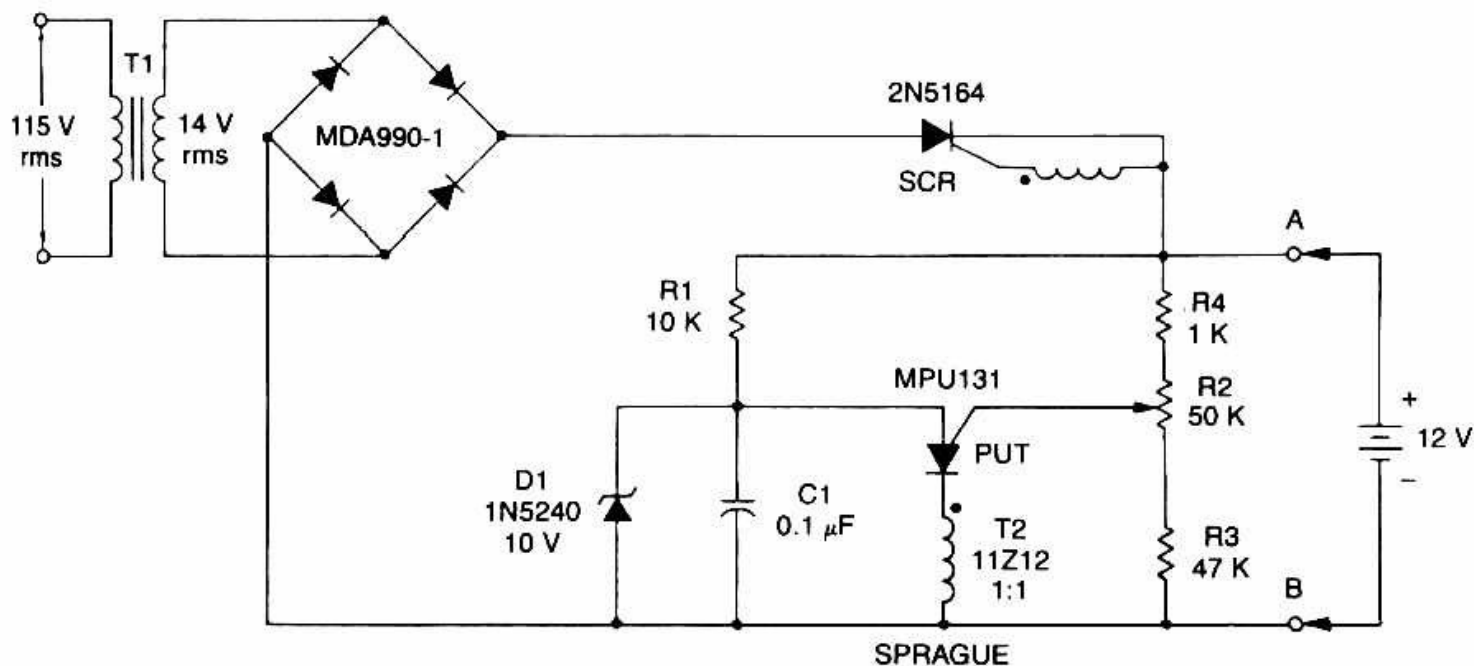


WILLIAM SHEETS

Fig. 1-25

This zapper clears internal shorts in nickel-cadmium batteries by burning them away. CAUTION: The negative battery terminal is connected to one side of the ac line. For safe operation, use a 1:1 isolation transformer.

PUT BATTERY CHARGER

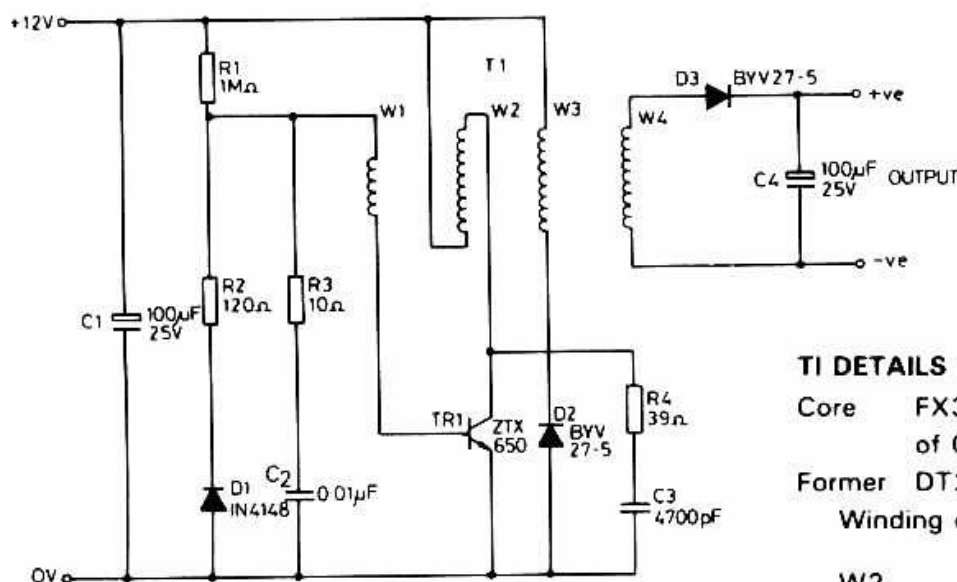


MOTOROLA

Fig. 1-26

A short-circuit-proof battery charger will provide an average charging current of about 8 A to a 12-V lead/acid storage battery. The charger circuit has an additional advantage; it will not function nor will it be damaged by improperly connecting the battery to the circuit. With 115 V at the input, the circuit commences to function when the battery is properly attached. The battery provides the current to charge the timing capacitor C1 used in the PUT relaxation oscillator. When C1 charges to the peak point voltage of the PUT, the PUT fires turning the SCR on, which in turn applies charging current to the battery. As the battery charges, the battery voltage increases slightly which increases the peak point voltage of the PUT. This means that C1 has to charge to a slightly higher voltage to fire the PUT. The voltage on C1 increases until the zener voltage of D1 is reached, which clamps the voltage on C1, and thus prevents the PUT oscillator from oscillating and charging ceases. The maximum battery voltage is set by potentiometer R2 which sets the peak point firing voltage of the PUT. In the circuit shown, the charging voltage can be set from 10 V to 14 V—the lower limit being set by D1 and the upper limit by T1.

PORTABLE NICAD BATTERY CHARGER



TI DETAILS

Core FX3437 With Gap/Spacer
of 0.08mm

Former DT2492

Winding order W2, W4, W3 then W1

W2	40T	30awg.
W4	20T	30awg.
W3	13T	36awg.
W1	12T	36awg.

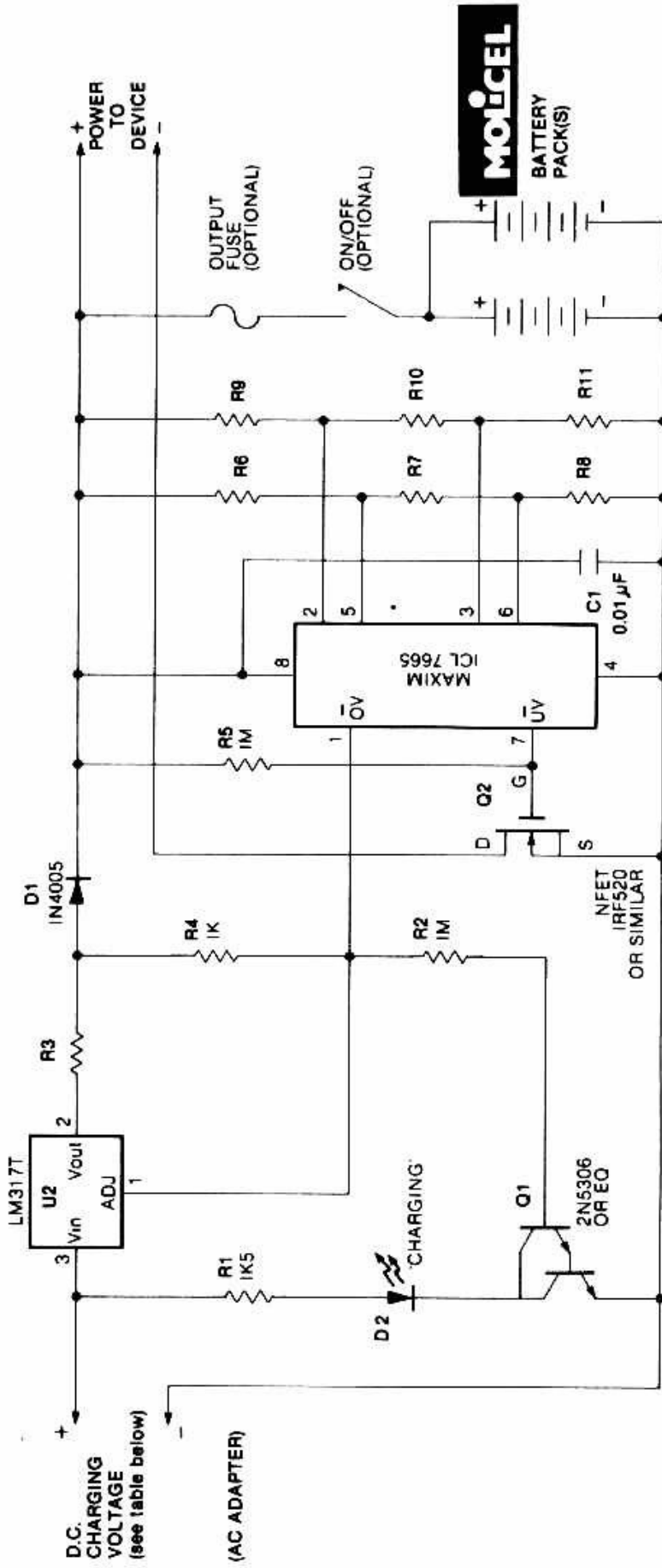
ZETEX (formerly FERRANTI)

Fig. 1-27

This circuit was designed to charge NiCad battery packs in the range of 4.8 to 15.6 V from a convenient remote power source, such as an automobile battery. When power is first applied to the circuit, a small bias current supplied by R1 via winding W1, starts to turn on the transistor TR1. This forces a voltage across W2 and the positive feedback given by the coupling of W1 and W2 causes the transistor to turn hard on, applying the full supply across W2. The base drive voltage induced across W1 makes the junction between R1 and R2 become negative with respect to the 0-V supply, forward-biasing diode D1 to provide the necessary base current to hold TR1 on.

With the transistor on, a magnetizing current builds up in W2, which eventually saturates the ferrite core of transformer T1. This results in a sudden increase on the collector current flowing through TR1, causing its collector-emitter voltage to rise, and thus reducing the voltage across W2. The current flowing in W2 forces the collector voltage of the TR1 to swing positive until restricted by transformer output loading. R_c network R4 and C3 limits the turn off transient TR1. R3 and C2 maintain the loop gain of the circuit when diode D1 is not conducting.

LITHIUM BATTERY CHARGER



MOLI ENERGY LIMITED

Fig. 1-28

Charging is accomplished with a constant current of 60 mA for AA cells to a cutoff voltage of 2.4 V per cell, at which point the charge must be terminated. The charging system shown is designed for multi-cell battery packs of 2 to 6 series-connected cells or series/parallel arrangements. It is essential that all cells assembled in the pack are at an identical state-of-charge (voltage) before charging. The maximum upper cut-off voltage is 15.6 V (6 x 2.6 V).

RAPID BATTERY CHARGER FOR ICOM IC-2A

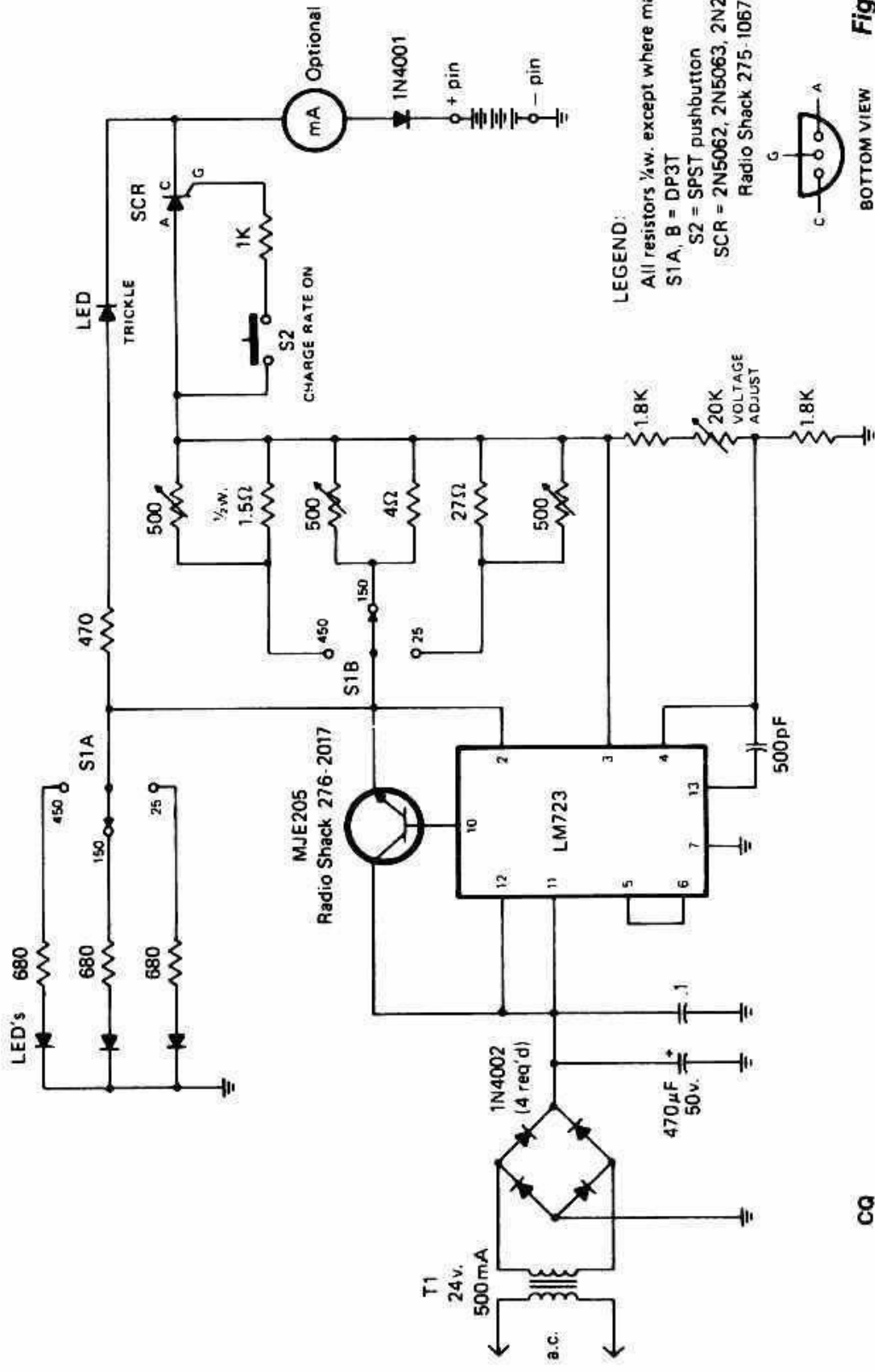
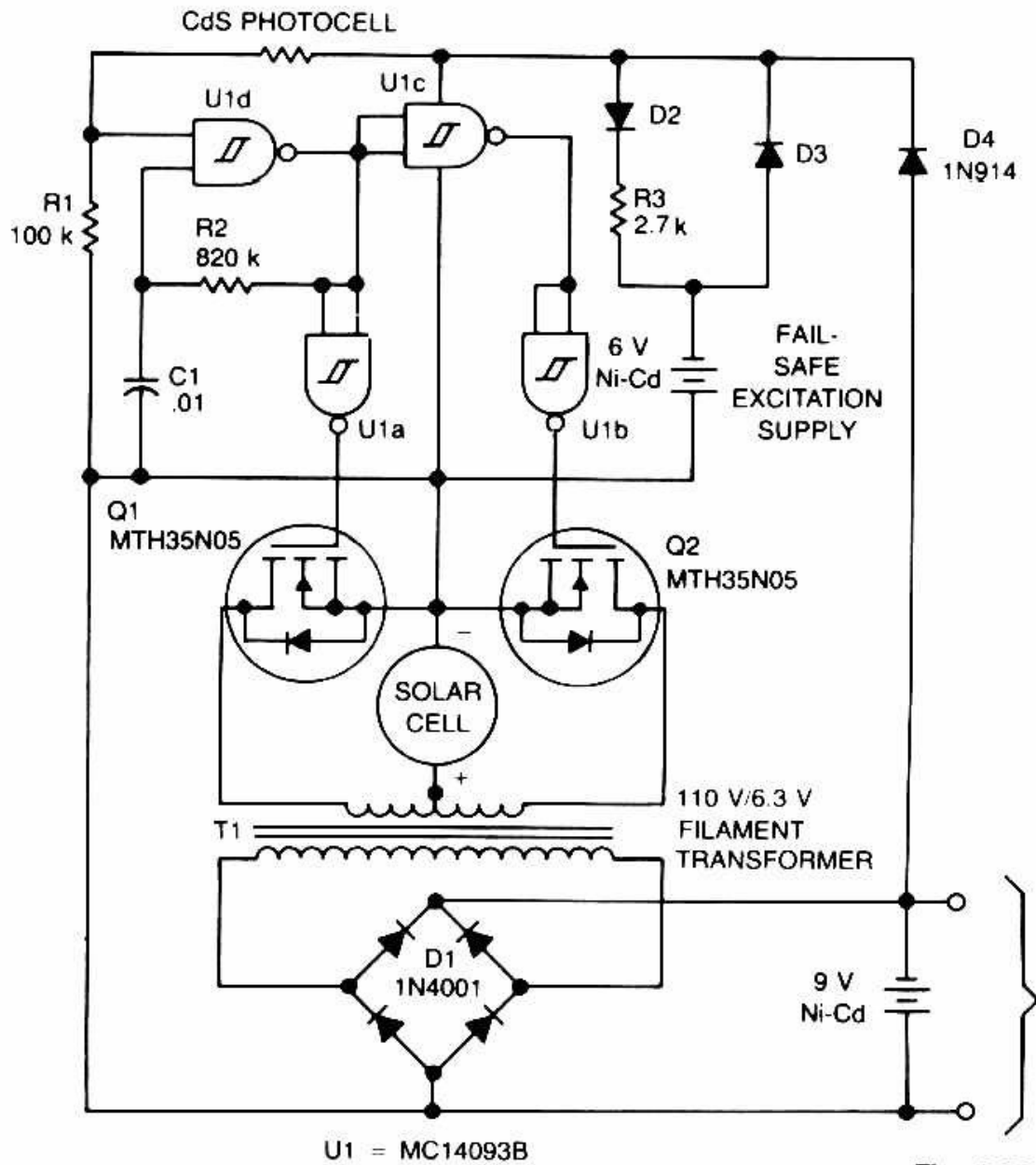


Fig. 1-29

CQ

Rectified and filtered voltage from the 24-Vac transformer is applied to the LM723 voltage regulator and the npn pass transistor set up for constant current supply. The 470-Ω resistor limits trickle current until the momentary pushbutton (S2) is depressed, the SCR turns on, and current flows through the previously determined resistor network, which limits the charging current. The SCR will turn off when the thermal cutout circuit inside the battery pack opens up.

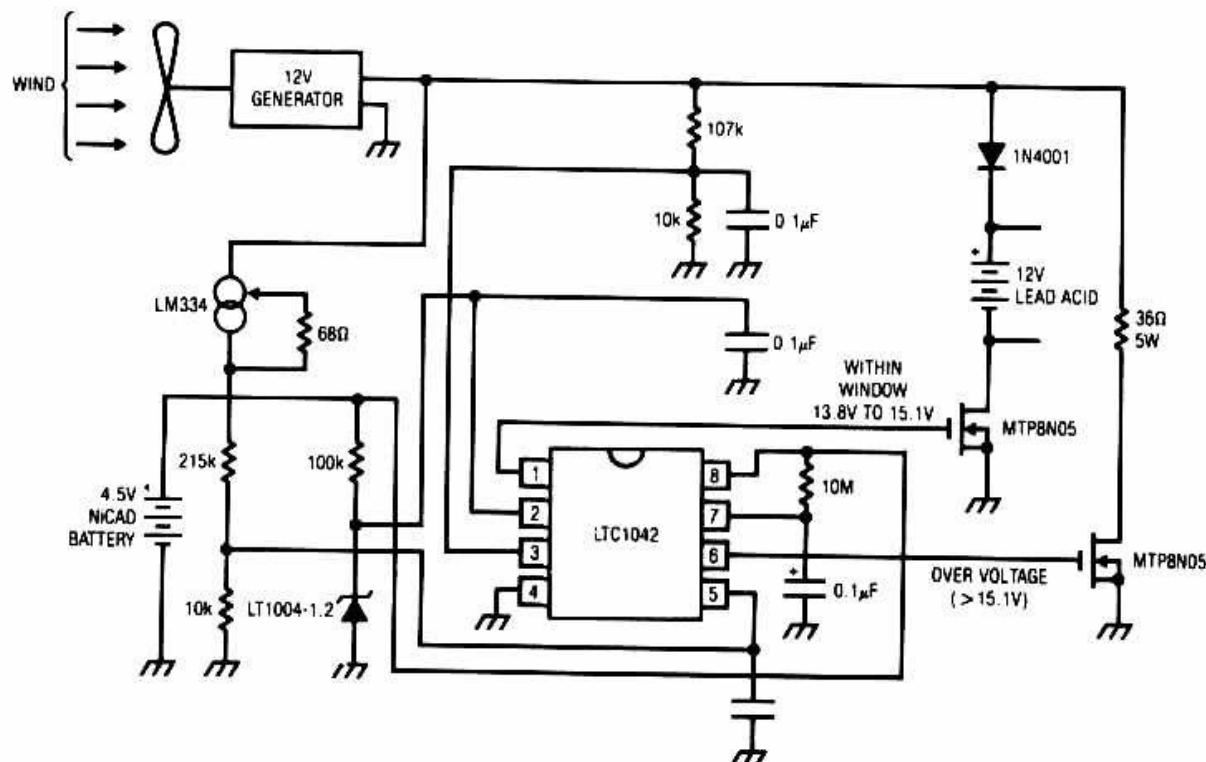
BATTERY CHARGER OPERATES ON SINGLE SOLAR CELL



The circuit charges a 9-V battery at about 30 mA per input ampere at 0.4 V. U1, a quad Schmitt trigger, operates as an astable multivibrator to drive push-pull TMOS devices, Q1 and Q2. Power for U1 is derived from the 9-V battery via D4; power for Q1 and Q2 is supplied by the solar cell. The multivibrator frequency, determined by R2/C1, is set to 180 Hz for maximum efficiency from a 6.3-V filament transformer, T1. The secondary of the transformer is applied to a full-wave bridge rectifier, D1, which is connected to the batteries being charged. The small NiCad battery is a fail-safe excitation supply to allow the system to recover if the 9-V battery becomes fully discharged.

A CdS photocell shuts off the oscillator in darkness to preserve the fail-safe battery during shipping, storage, and prolonged darkness.

WIND-POWERED BATTERY CHARGER



LINEAR TECHNOLOGY

Fig. 1-31

The dc motor is used as a generator; the voltage output is proportional to its rpm. The LTC1042 monitors the voltage output and provides the following control functions.

1. If generator voltage output is below 13.8 V, the control circuit is active and the NiCad battery is charging through the LM334 current source. The lead-acid battery is not being charged.
2. If the generator voltage output is between 13.8 and 15.1 V, the 12-V lead-acid battery is being charged at about 1-amp/hour rate (limited by the power FET).
3. If generator voltage exceeds 15.1 V (a condition caused by excessive wind speed or when the 12-V battery is fully charged), then a fixed load is connected, which limits the generator rpm to prevent damage.

This charger can be used as a remote source of power where wind energy is plentiful, such as on sailboats or at remote radio repeater sites. Unlike solar-powered panels, this system will function in bad weather and at night.

2

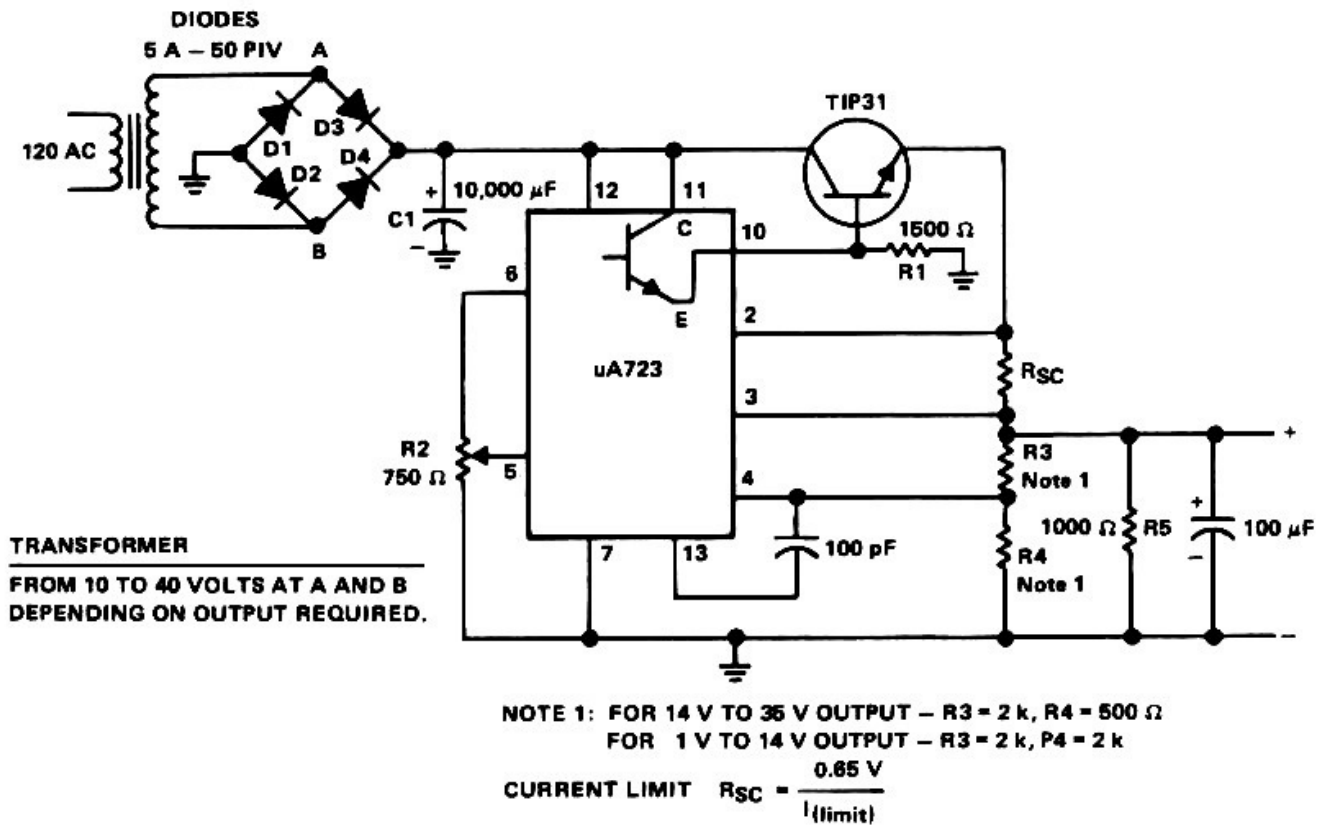
Power Supplies—Fixed

The sources of the following circuits are contained in the Sources section, which begins on page 125. The figure number in the box of each circuit correlates to the source entry in the Sources section.

- General-Purpose Power Supply
- 12-Vdc Battery-Operated 120-Vac Power Source
- Simple Power Supply
- Charge-Pool Power Supply
- Bilateral Current Source
- 3- to 30-V Universal Power-Supply Module
- Regulator/Current Source
- Low-Power Switching Regulator
- Variable Voltage Regulator
- Switching Power Supply
- 100-kHz Multiple-Output Switching Power Supply
- Isolated Feedback Power Supply
- Dual-Tracking Regulator
- +15-V 1-A Regulated Power Supply
- 15-V 1-A Regulated Power Supply
- Hand-Held Transceiver dc Adapter
- Low-Dropout 5-V Regulator
- Triac-Controlled Voltage Doubler
- High-Stability 10-V Regulator
- Voltage-Controlled Current Source
- Low-Power Inverter
- Three-Rail Power Supply
- Programmable Power Supply
- Efficient Negative Voltage Regulator
- 5 V-to-Isolated 5 V (at 20 mA) Converter
- Positive Regulator with npn and pnp Boost
- Tracking Preregulator
- Adjustable 10-A Regulator
- Low-Cost Low-Dropout Linear Regulator
- Voltage Doubler
- Safe Constant-Current Source
- Low-Cost 3-A Switching Regulator
- 50-W Off-Line Switching Power Supply
- Positive Regulator with pnp Boost
- Low Forward-Drop Rectifier Circuit
- Low-Ripple Power Supply
- 5.0-V/10-A Regulator
- 5.0-V/3.0-A Regulator
- Bench-Top Power Supply
- Variable Current Source (100 mA to 2 A)

Basic Single-Supply Voltage Regulator
 8-A Regulated Power Supply for Operating Mobile Equipment
 Low-Voltage Regulators with Short-Circuit Protection
 High-Stability 1-A Regulator
 High-Current Inductorless Switching Regulator
 200-kHz Switching Regulator
 5-V 0.5-A Power Supply
 3-W Switching-Regulator Circuit
 Regulated Split Power Supplies from a Single Supply
 Switching Step-Down Regulator
 Single-Ended Regulator
 ± 50 -V Push-Pull Switched-Mode Converter
 5-V/0.5-A Buck Converter
 Slow Turn-On 15-V Regulator
 ac Voltage Regulator
 Uninterruptible +5-V Supply
 Stand-By Power For Nonvolatile CMOS RAMs
 5-V Supply With Stabilized Momentary Backup
 Uninterruptible Power Supply for Personal Computers
 90-Vrms Voltage Regulator Using a PUT
 Switch-Mode Power Supply
 Micropower Bandgap Reference Supply
 ± 50 -V Feed-Forward Switch-Mode Converter
 Traveller's Shaver Adapter
 100-V/0.25-A Switch-Mode Converter
 Voltage Regulator
 Dual-Polarity Power Supply
 5.0-V/6.0-A/25-kHz Switching Regulator With Separate Ultra-Stable Reference
 Mobile Voltage Regulator
 Negative Switching Regulator
 Positive Switching Regulator
 Positive Floating Regulator
 Negative Floating Regulator
 Negative Voltage Regulator
 -15-V Negative Regulator
 Slow Turn-On 15-V Regulator
 High-Stability 10-V Regulator
 5-V/1-A Switching Regulator
 15-V/1-A Regulator with Remote Sense
 Increasing the Power Rating of Zener Diodes
 Voltage Regulator
 Zener Diode Regulator
 12- to 14-V Regulated 3-A Power Supply
 dc-to-dc SMPS Variable (18 to 30 V Out at 0.2 A)
 SCR Preregulator Fits Any Power Supply
 Off-Line Flyback Regulator
 500-kHz Switching Inverter for 12-V Systems
 10-A Regulator with Current and Thermal Protection
 Bipolar Power Supply For Battery Instruments
 Power Supply for 25-W Arc Lamp
 Power-Switching Circuit
 100-V/0.25-A Switch Mode Converter
 Radiation-Hardened 125-A Linear Regulator
 Supply Voltage Splitter
 3- to 5-V Regulated Output Converter
 Memory-Save On Power-Down
 100-Vrms Voltage Regulator

GENERAL-PURPOSE POWER SUPPLY



TEXAS INSTRUMENTS

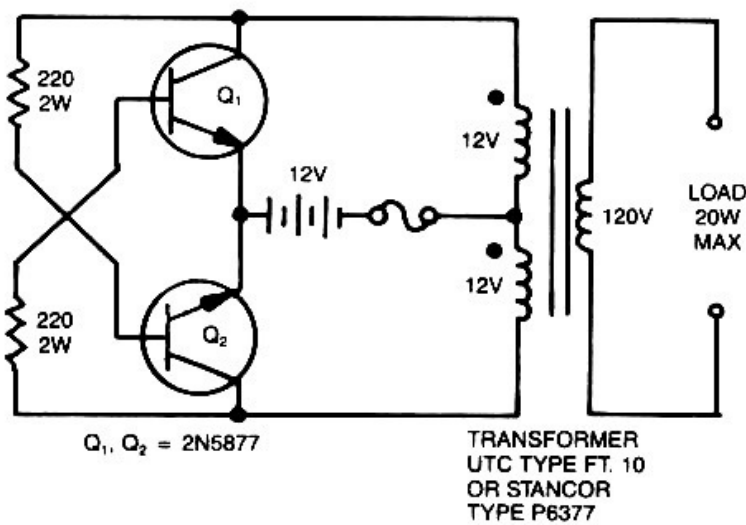
Fig. 2-1

The supply can be used for supply output voltages from 1 to 35 V. The line transformer should be selected to give about 1.4 times the desired output voltage from the positive side of filter capacitor C1 to ground. Potentiometer R2 sets the output voltage to the desired value by adjusting the reference input. R_{SC} is the current limit set resistor. Its value is calculated as:

$$R_{SC} = \frac{0.65 \text{ V}}{I_L}$$

For example, if the maximum current output is to be 1 A, $R_{SC} = 0.65/1.0 = 0.65 \Omega$. The 1-kΩ resistor, R_S, is a light-loaded resistor designed to improve the no-load stability of the supply.

12-Vdc BATTERY-OPERATED 120-Vac POWER SOURCE



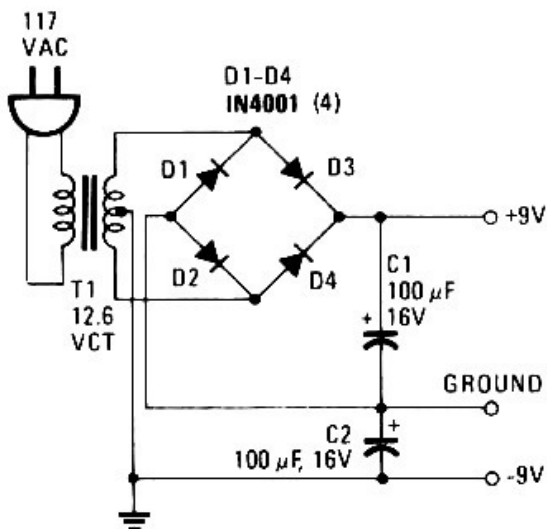
EDN

Fig. 2-2

A simple 120 V: 24 V, center-tapped control transformer and four additional components can do the job. This circuit outputs a clean 200-V pk-pk square wave at 60 Hz and can supply up to 20 W. The circuit is self-starting and free-running.

If Q1 is faster and has a higher gain than Q2, it will turn on first when you apply the input power and will hold Q2 off. Load current and transformer magnetizing current then flows in the upper half of the primary winding, and auto transformer action supplies the base drive until the transformer saturates. When that action occurs, Q1 loses its base drive. As it turns off, the transformer voltages reverse, turning Q2 on and repeating the cycle. The output frequency depends on the transformer iron and input voltage, but not on the load. The frequency will generally range between 50 to 60 Hz with a 60-Hz transformer and car battery or equivalent source. The output voltage depends on turns ratio and the difference between input voltage and transistor saturation voltage. For higher power, use larger transformers and transistors. This type of inverter normally is used in radios, phonographs, hand tools, shavers, and small fluorescent lamps. It will not work with reactive loads (motors) or loads with high inrush currents, such as coffee pots, frying pans, and heaters.

SIMPLE POWER SUPPLY



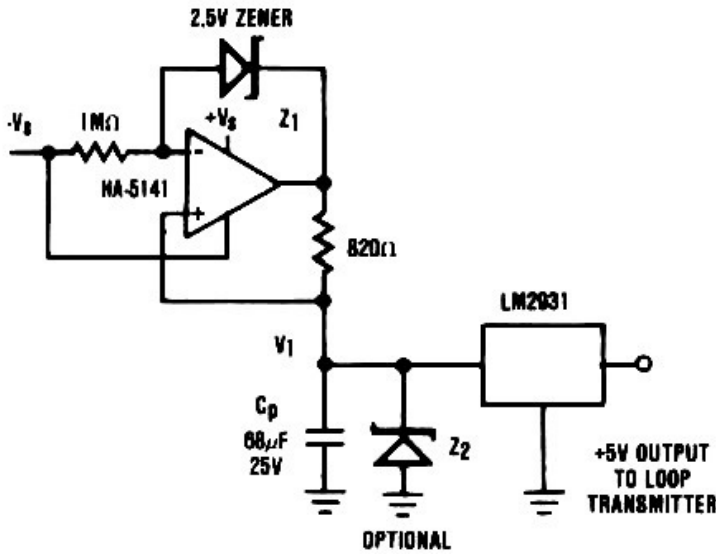
HANDS-ON ELECTRONICS

Fig. 2-3

This power supply delivers plus and minus 9 V to replace two 9-V batteries. The rectifier circuit is actually two separate full-wave rectifiers fed from the secondary of the transformer. One full-wave rectifier is composed of diodes D1 and D2, which develop +9 V, and the other is composed of D3 and D4, which develop -9 V.

Each diode from every pair rectifies 6.3 Vac, half the secondary voltage, and charges the associated filter capacitor to the peak value of the ac waveform, $6.3 \times 1.414 = 8.9$ V. Each diode should have a PIV, Peak Inverse Voltage, rating that is at least twice the peak voltage from the transformer, $2 \times 8.9 = 18$ V. The 1N4001 has a PIV of 50 V.

CHARGE-POOL POWER SUPPLY



HARRIS

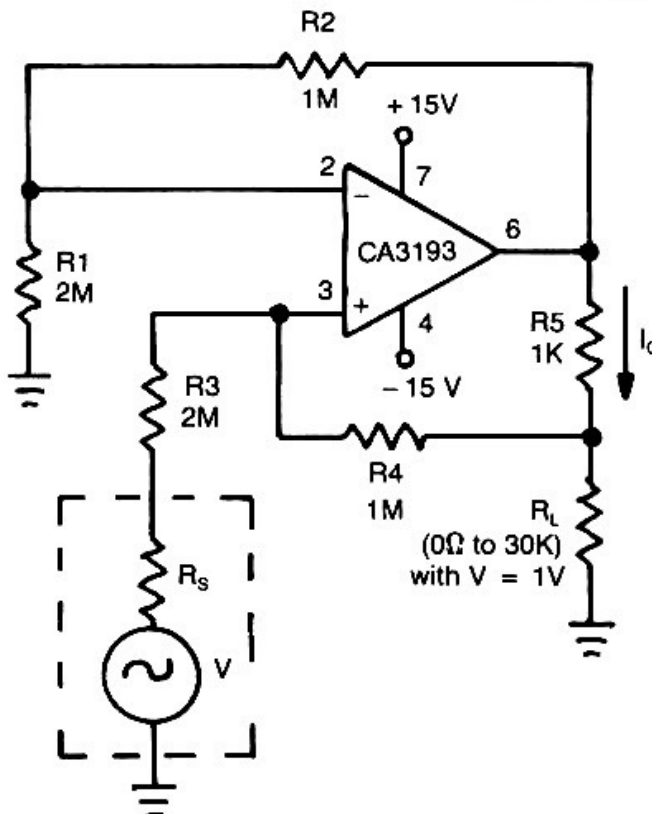
Fig. 2-4

It is usually desirable to have the remote transmitter of a 4- to 20-mA current loop system powered directly from the transmission line. In some cases, this is not possible because of the high-power requirements set by the remote sensor/transmitter system. In these cases, an alternative

to the separate power supply is still possible. If the remote transmitter can be operated in a pulsed mode where it is active only long enough to perform its function, then a charge pool power supply can still allow the transmitter to be powered directly by the current loop. In this circuit, constant current I_1 is supplied to the charge pool capacitor, CP, by the HA-5141 (where $I_1 = 3$ mA). The voltage V_1 continues to rise until the output of the HA-5141 approaches $+V_s$ or the optional voltage limiting provided by Z2. The LM2931 voltage regulator supplies the transmitter with a stable +5-V supply from the charge collected by CP. Available power supply current is determined by the duration, allowable voltage drop on CP, and required repetition rate. For example, if V_1 is allowed to drop 4.4 V and the duration of operation is 1 ms, the available power supply current is approximately:

$$= CP \frac{dV_1}{dt} = 68 \mu\text{F} \times \frac{4.4 \text{ V}}{1 \text{ ms}} = 30 \text{ mA}$$

BILATERAL CURRENT SOURCE



This circuit uses a CA3193 precision op amp to deliver a current independent of variations in R_L . With R_1 set equal to R_3 , and R_2 approximately equal to $R_4 + R_5$, the output current, I_L , is: $V_{IN} (R_4)/(R_3) (R_5)$. 500- μA load current is constant for load values from 0 to 3 Ω .

ALL RESISTORS ARE 1%
ALL RESISTANCE VALUES ARE IN OHMS
IF $R_1 = R_3$ AND $R_2 \approx R_4 + R_5$ THEN

I_L IS INDEPENDENT OF VARIATIONS IN R_L
FOR R_L VALUES OF 0 Ω TO 3K Ω WITH $V = 1\text{V}$

$$I_L = \frac{V R_4}{R_3 R_5} = \frac{V 1\text{M}}{(2\text{M})(1\text{K})} = \frac{V}{2\text{K}} = 500\mu\text{A}$$

GE/RCA

Fig. 2-5

3- to 30-V UNIVERSAL POWER-SUPPLY MODULE

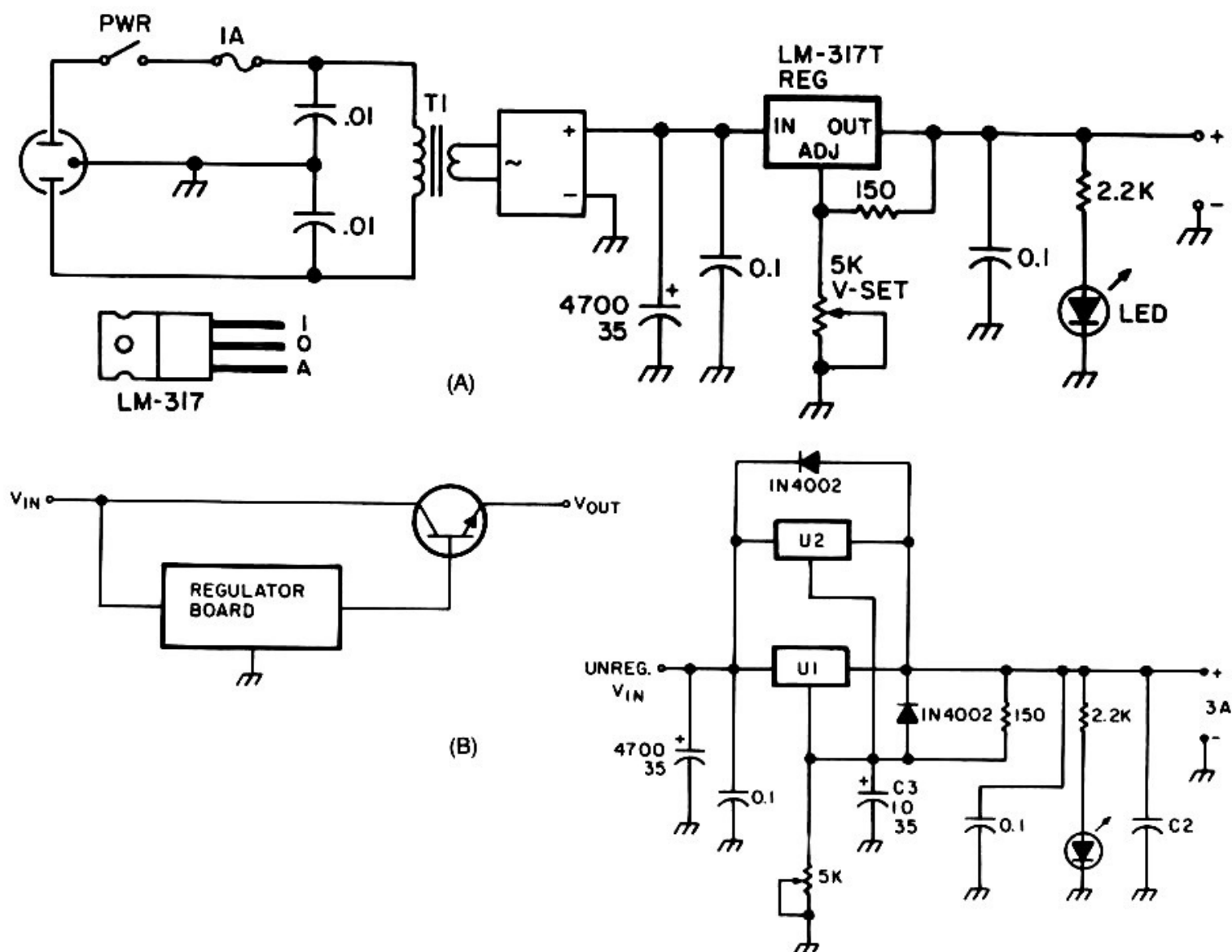


Fig. 2-6

73 AMATEUR RADIO

U1, an LM317 adjustable regulator provides short-circuit protection and automatic current limiting at 1.5 A. The input voltage to the regulator is supplied by DB1, a 4-A 100 PIV full-wave bridge rectifier. Capacitor C1 provides initial filtering. U1 provides additional electronic filtering as part of the regulating function. The output level of the regulator is set by trim-pot R1. Bypass capacitors on the input and output of U1 prevent high-frequency oscillation. The current rating of the transformer must be at least 1.8 times the rated continuous-duty output of the supply. This means that a 1.5-A supply should use a 2.7-A transformer. For light or intermittent loads, a smaller 2.0-A transformer should suffice.

Wiring a second LM317, U2, in parallel with U1 is a quick and clean way to increase the current-limiting threshold to 3 A without sacrificing short-circuit protection. When more than 3 A is required, the regulator module can be used to drive the base of one or more pass-transistors (see Fig. 2-6B).

REGULATOR/CURRENT SOURCE

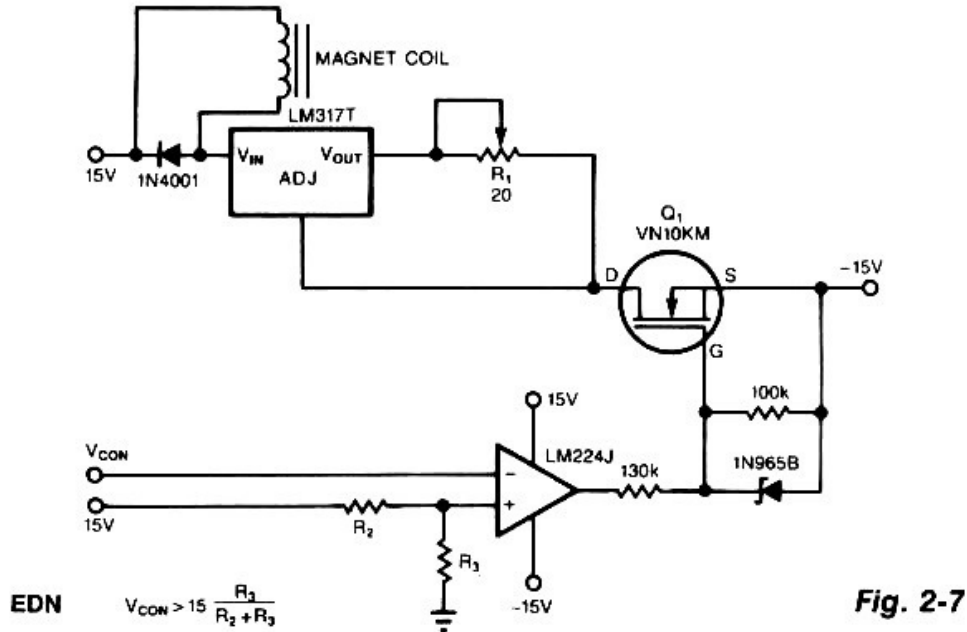
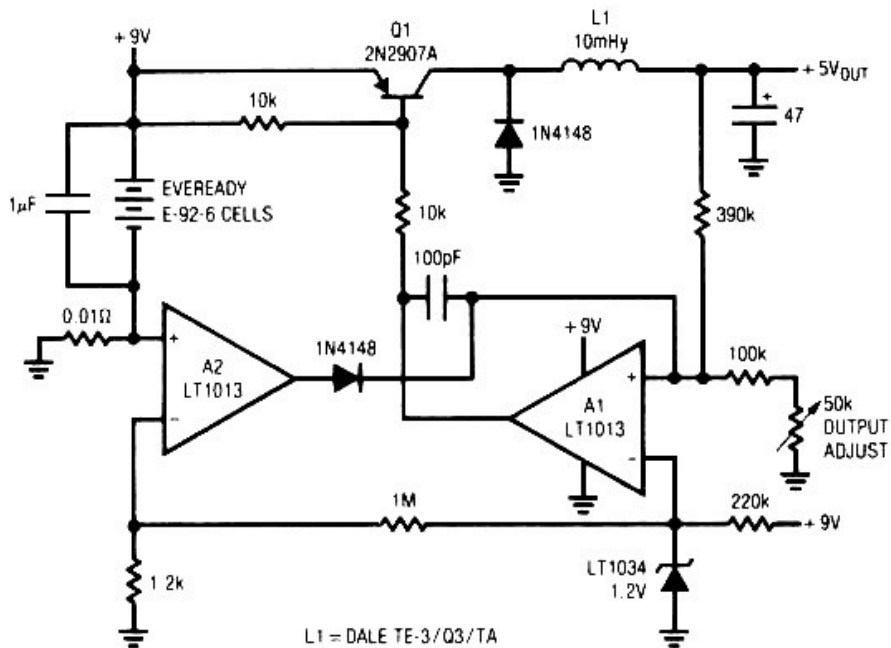


Fig. 2-7

The circuit powers the load via the regulator's input instead of its output. Because the regulator's output sees constant dummy load R1, it tries to consume a constant amount of current, no matter what the voltage across the actual load really is. Hence, the regulator's input serves as a constant-current source for the actual load. Power the circuit with any one of the commonly available ± 15 - or ± 12 -V supplies. The voltage dropped across the regulator and dummy load decreased the total compliance voltage of the circuit. You set the load's current with R1. The current equals $1.25 \text{ A}/\Omega \times R_1$.

LOW-POWER SWITCHING REGULATOR



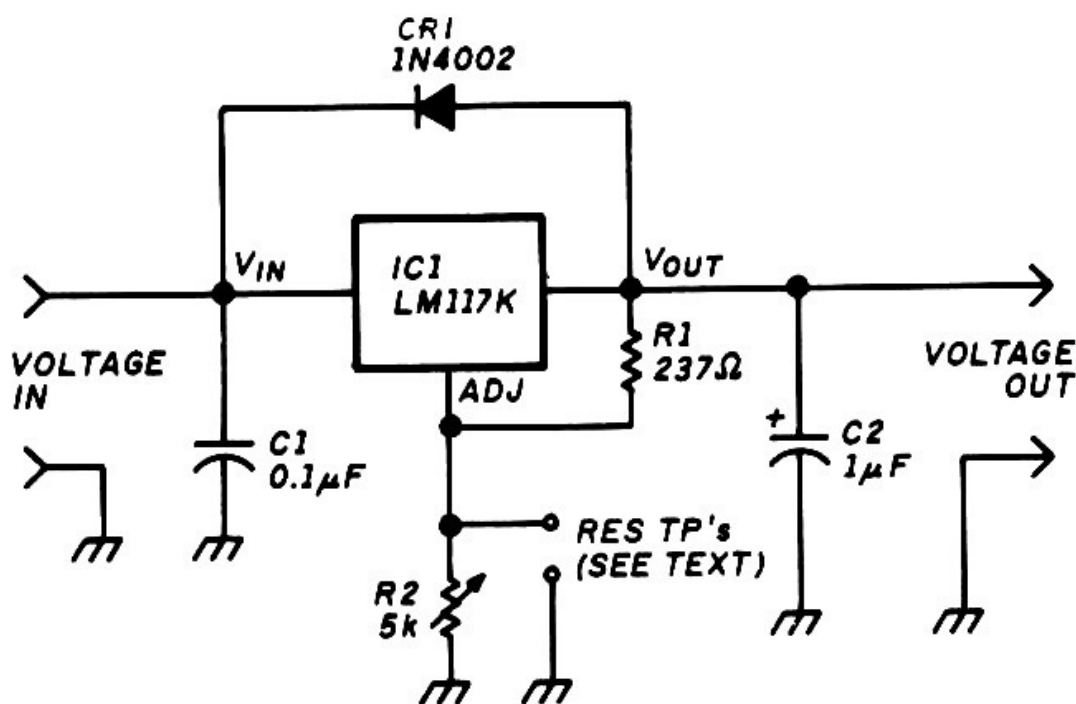
LINEAR TECHNOLOGY CORP.

Fig. 2-8

LOW-POWER SWITCHING REGULATOR (cont.)

A simple battery-powered switching regulator provides 5 V out from a 9-V source with 80% efficiency and 50-mA output capability. When Q1 is on, its collector voltage rises, forcing current through the inductor. The output voltage rises, causing A1's output to rise. Q1 cuts off and the output decays through the load. The 100-pF capacitor ensures clean switching. The cycle repeats when the output drops low enough for A1 to turn on Q1. The 1- μ F capacitor ensures low battery impedance at high frequencies, preventing sag during switching.

VARIABLE VOLTAGE REGULATOR

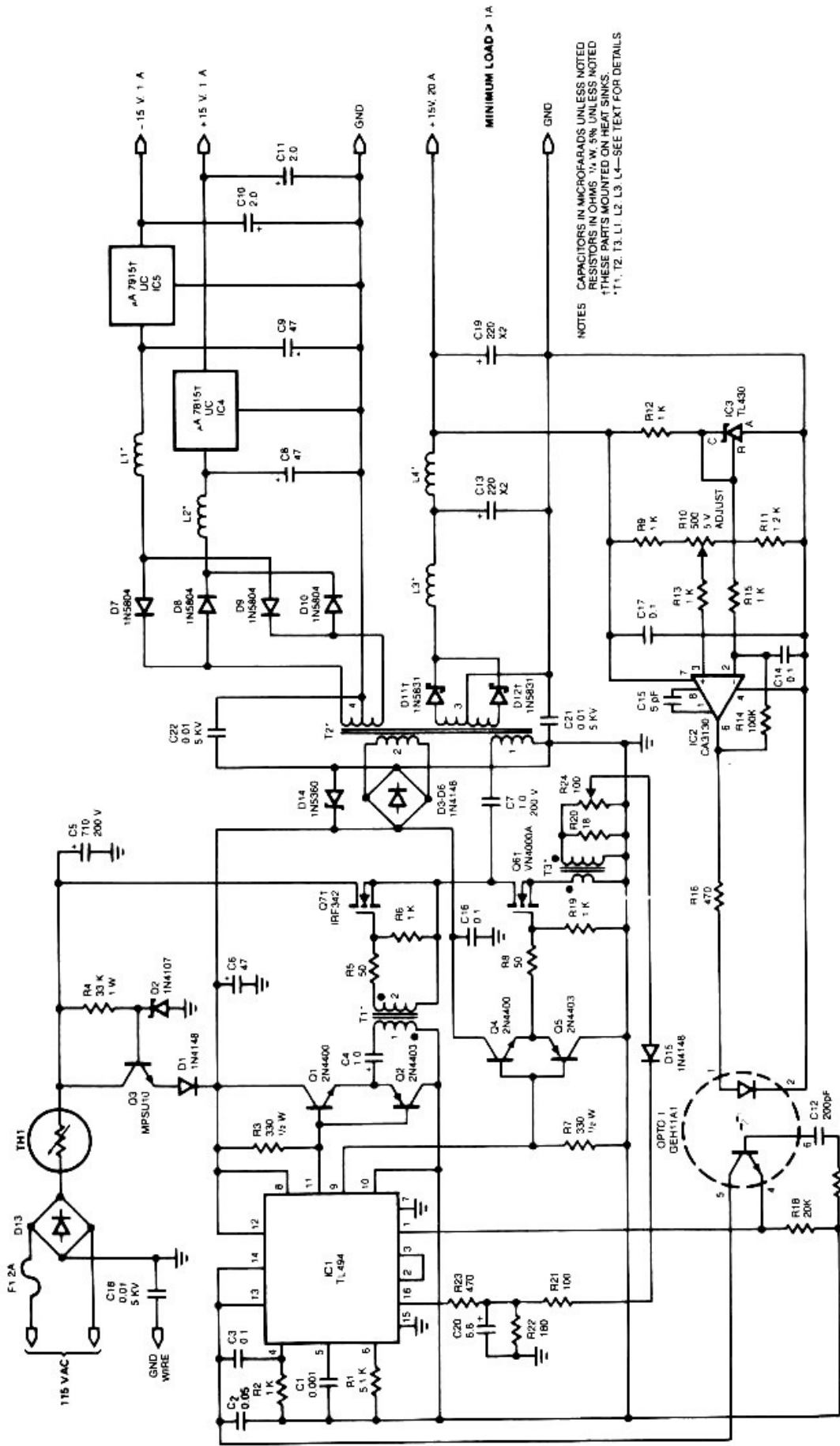


HAM RADIO

Fig. 2-9

The variable voltage regulator lets you adjust the output voltage of a fixed dc power supply between 1.2 and 37 Vdc, and will supply the output current in excess of 1.5 A. The circuit incorporates an LM117K three-terminal adjustable output positive voltage regulator in a TO-3 can. Thermal overload protection and short-circuit current-limiting constant with temperature are included in the package. Capacitor C1 reduces sensitivity to input line impedance, and C2 reduces excessive ringing. Diode CR1 prevents C2 from discharging through the IC during an output short.

100-KHZ MULTIPLE-OUTPUT SWITCHING POWER SUPPLY



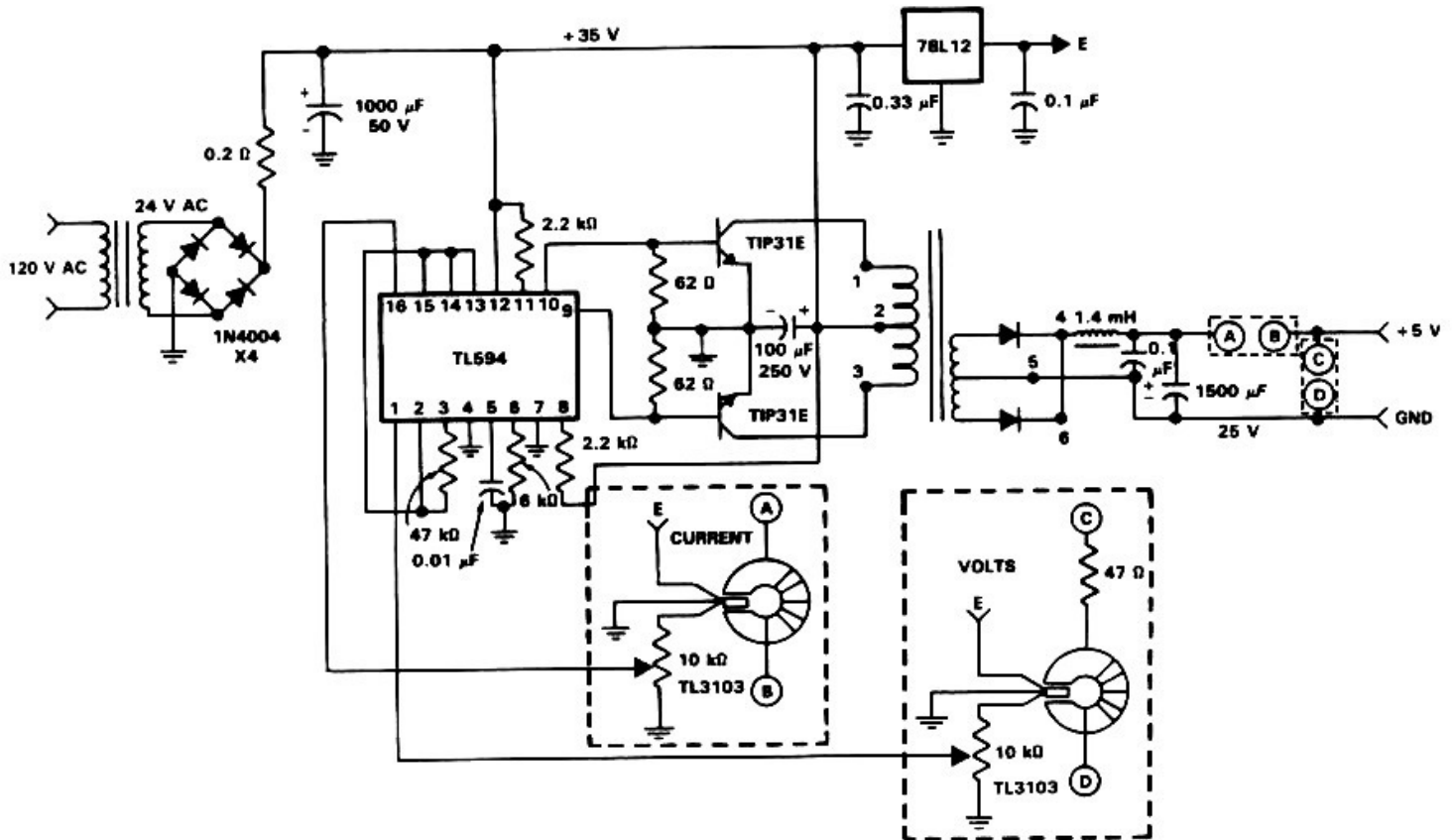
NOTES
 CAPACITORS IN MICROFARADS UNLESS NOTED
 RESISTORS IN OHMS 1/4 W, 5% UNLESS NOTED
 † THESE PARTS MOUNTED ON HEAT SINKS.
 * T1, T2, T3, L1, L2, L3, L4—SEE TEXT FOR DETAILS

Fig. 2-11

SILICONIX

The power supply uses two VN4000A 400-V MOSPOWER FETs in a half-bridge power switch configuration. Outputs available are +5 V at 20 A and ±15 V (or ±12 V) at 1 A. Since linear three-terminal regulators are used for the low-current outputs, either ±12 V or ±15 V can be made available with a simple change in the transformer secondary windings. A TL494 switching regulator IC provides pulse-width modulation control and drive signals for the power supply. The upper MOSPOWER FET, Q7, in the power switch stage is driven by a simple transformer drive circuit. The lower MOS, Q6, since it is ground referenced, is directly driven from the control IC.

ISOLATED FEEDBACK POWER SUPPLY



TEXAS INSTRUMENTS

Fig. 2-12

Figure 2-12 is a power supply circuit using the isolated feedback capabilities of the TL3103 for both current and voltage sensing. This supply is powered from the ac power line and has an output of 5 V at 1.5 A. Both output voltage and current are sensed and the error voltages are applied to the error amplifiers of the TL594 PWM control IC. The 24-V transformer produces about 35 V at the 1000- μ F filter capacitor. The 20-kHz switching frequency is set by the 6-k Ω resistor and the 0.01- μ F capacitor on pins 6 and 5, respectively. The TL594 is set for push-pull operation by tying pin 13 high. The 5-V reference on pin 14 is tied to pin 15, which is the reference of the current error amplifier. The 5-V reference is also tied to pin 2 which is the reference for the output voltage error amplifier. The output voltage and current limit are set by adjustment of the 10-k Ω pots in the TL3103 error-sensing circuits. A pair of TIP31E npn transistors are used as switching transistors in a push-pull circuit.

DUAL-TRACKING REGULATOR

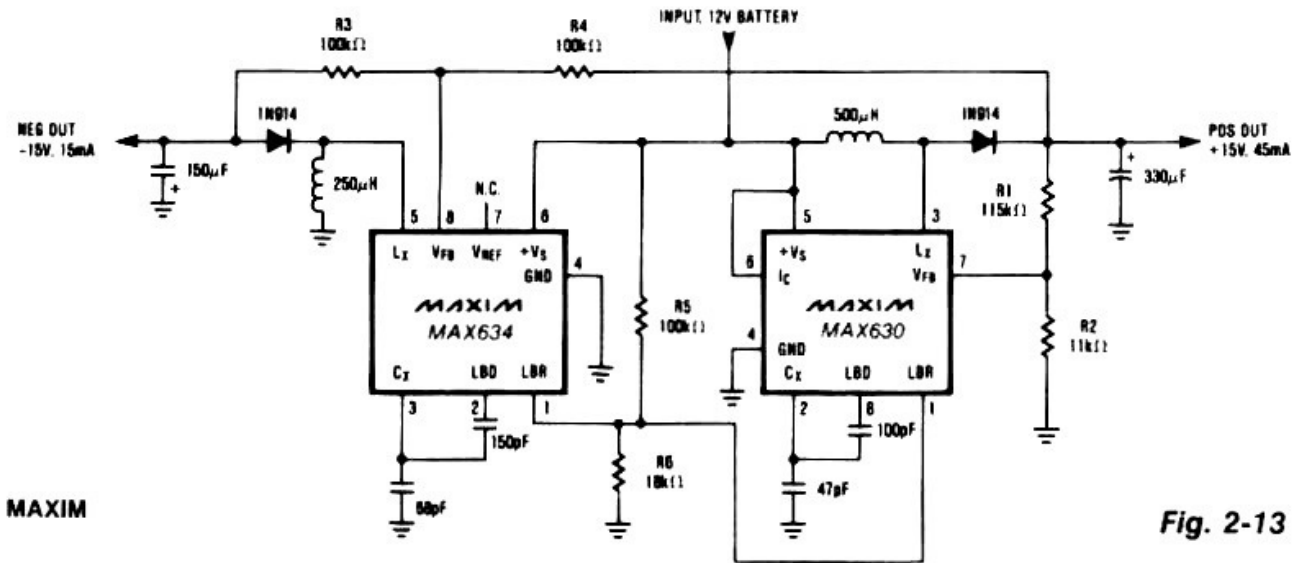


Fig. 2-13

A MAX634 inverting regulator is combined with a MAX630 to provide a dual tracking ± 15 -V output from a 12-V battery. The reference for the -15 -V output is derived from the positive output via R3 and R4. Both regulators are set to maximize output power at low battery voltages by reducing the oscillator frequency, via LBR, when V_{BATT} falls to 8.5 V.

+ 15-V 1-A REGULATED POWER SUPPLY

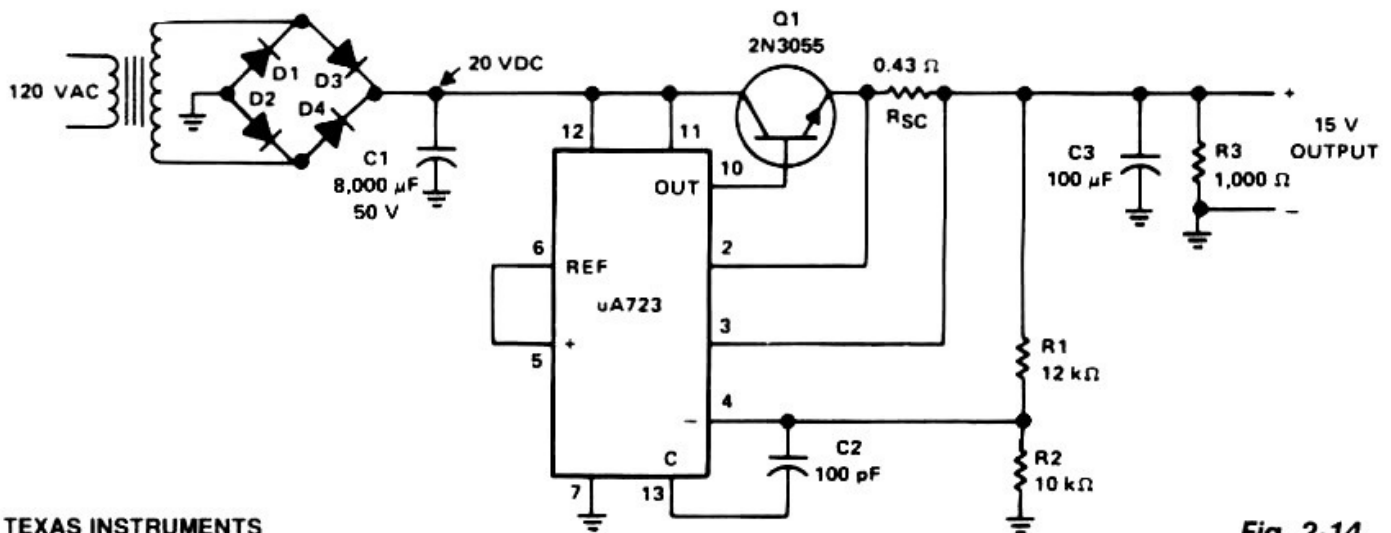


Fig. 2-14

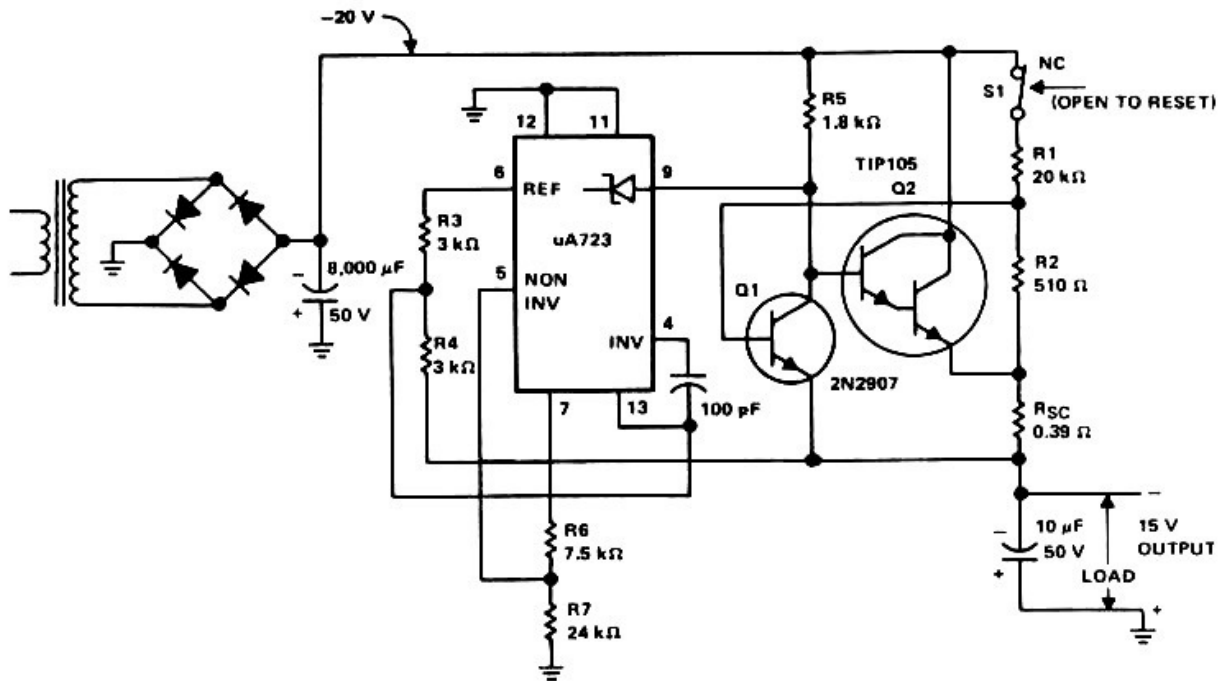
The supply receives +20 Vdc from the rectifier/filter section. This is applied to pins 11 and 12 of the uA723, as well as to the collector of the 2N3055 series-pass transistor. The output voltage is sampled through R1 and R2, providing about 7 V with respect to ground at pin 4. The reference terminal at pin 6 is tied directly to pin 5, the noninverting input of the error amplifier. For fine trimming the output voltage, a potentiometer can be installed between R1 and R2. A 100-pF capacitor from pin 13 to pin 4 furnishes gain compensation for the amplifier.

+ 15-V 1-A REGULATED POWER SUPPLY (cont.)

Base drive to the 2N3055 pass transistor is furnished by pin 10 of the $\mu\text{A}723$. Since the desired output of the supply is 1 A, maximum current limit is set to 1.5 A by resistor R_{SC} whose value is 0.433Ω .

A $100\text{-}\mu\text{F}$ electrolytic capacitor is used for ripple voltage reduction at the output. A $1\text{-k}\Omega$ output resistor provides stability for the power supply under no-load conditions. The 2N3055 pass transistor must be mounted on an adequate heatsink.

- 15-V 1-A REGULATED POWER SUPPLY

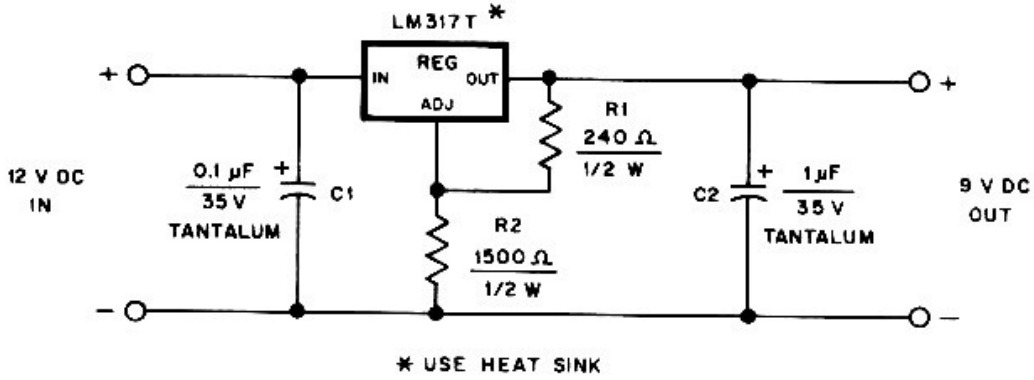


TEXAS INSTRUMENTS

Fig. 2-15

The supply receives -20 V from the rectifier/filter which is fed to the collector of the Darlington pnp pass transistor, a TIP105. The base drive to the TIP105 is supplied through resistor R_5 . The base of the TIP105 is driven from V_Z terminal at pin 9, which is the anode of a 6.2-V zener diode that connects to the emitter of the $\mu\text{A}723$ output control transistor. The method of providing the positive feedback required for foldback action is shown. This technique introduces positive feedback by increased current flow through resistors R_1 and R_2 under short-circuit conditions. This forward biases the base-emitter junction of the 2N2907 sensing transistor, which reduces base drive to the TIP105.

HAND-HELD TRANSCEIVER dc ADAPTER

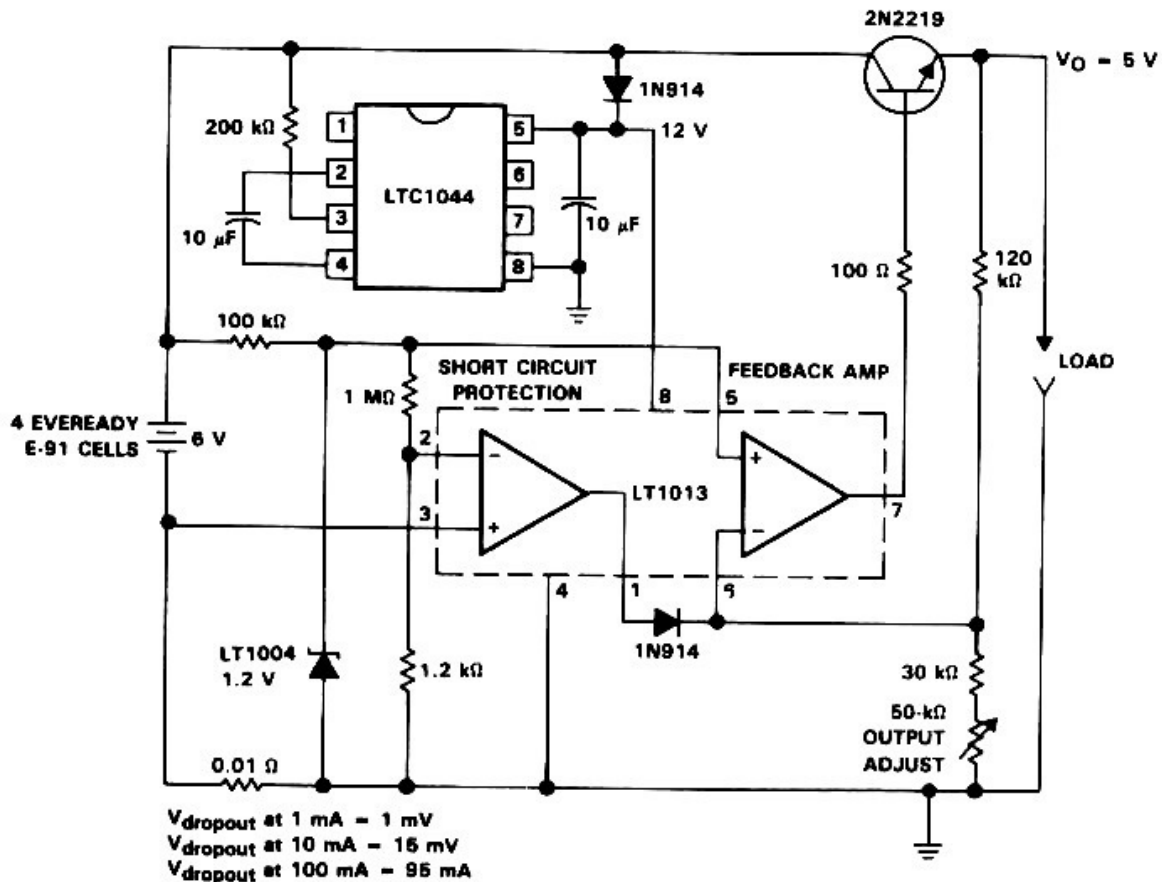


QST

Fig. 2-16

This dc adapter provides a regulated 9-V source for operating a Kenwood TR-2500 hand-held transceiver in the car. The LM317T's mounting tab is electrically connected to its output pin, so take this into account as you construct your version of the adapter. The LM317T regulator dissipates 2 or 3 W in this application, so mount it on a 1- \times -2-inch piece of 1/8-inch-thick aluminum heatsink.

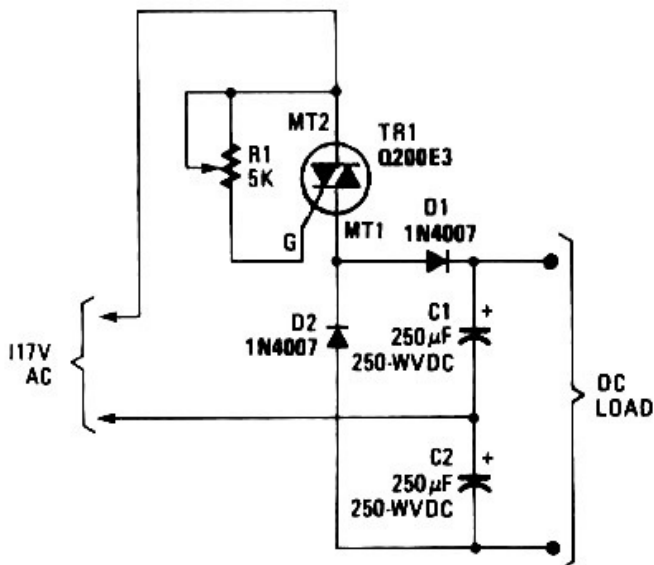
LOW-DROPOUT 5-V REGULATOR



TEXAS INSTRUMENTS

Fig. 2-17

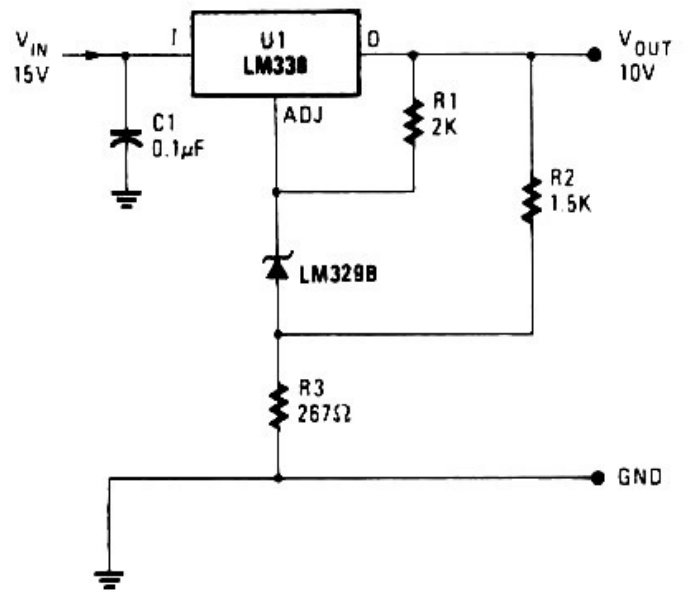
TRIAC-CONTROLLED VOLTAGE DOUBLER



HANDS-ON ELECTRONICS

Fig. 2-18

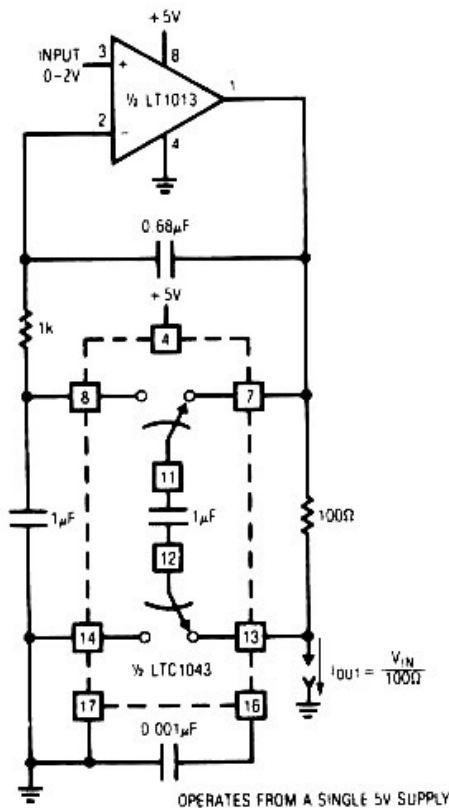
HIGH-STABILITY 10-V REGULATOR



POPULAR ELECTRONICS

Fig. 2-19

VOLTAGE-CONTROLLED CURRENT SOURCE

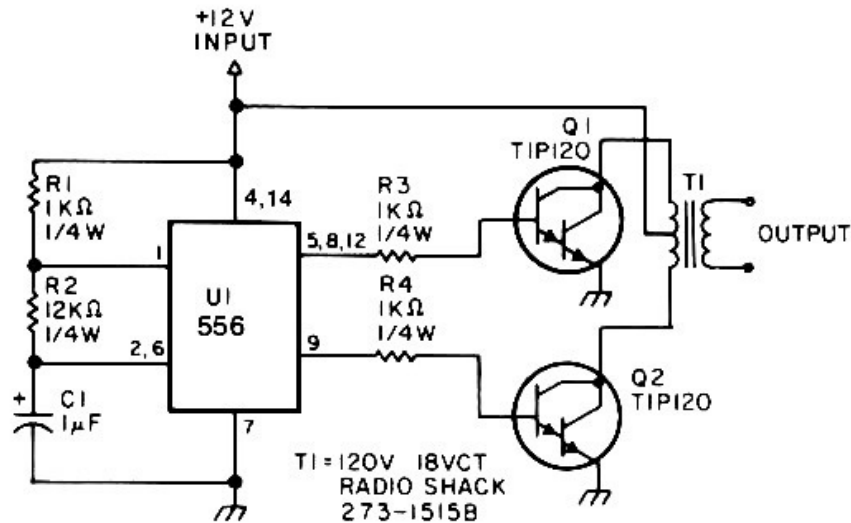


This is a simple, precise voltage-controlled current source. Bipolar supplies will permit bipolar output. Configurations featuring a grounded voltage-control source and a grounded load are usually more complex and depend upon several components for stability. In this circuit, accuracy and stability almost entirely depend upon the 100-Ω shunt.

LINEAR TECHNOLOGY CORP.

Fig. 7-20

LOW-POWER INVERTER



73 AMATEUR RADIO

Fig. 2-21

This low-power inverter uses only 9 parts and turns 10 to 16 Vdc into 60-Hz, 115-V square-wave power to operate ac equipment up to 25 W. The first section of the 556 timer chip is wired as an astable oscillator with R2 and C1 setting the frequency. The output is available at pin 5. The second section is wired as a phase inverter. That output is available at pin 9. Resistors R3 and R4 keep output transistors Q1 and Q2 from loading down the oscillator. The two transistors drive the transformer push-pull fashion. When one transistor is biased-on, the other is cut-off. The transformer is a 120 V/18 VCT unit that is connected backwards, so that it steps the voltage up rather than down. Oscillator circuit U1, R1, R2, and C1 operates from about 4 to 16 V with a very stable output.

THREE-RAIL POWER SUPPLY

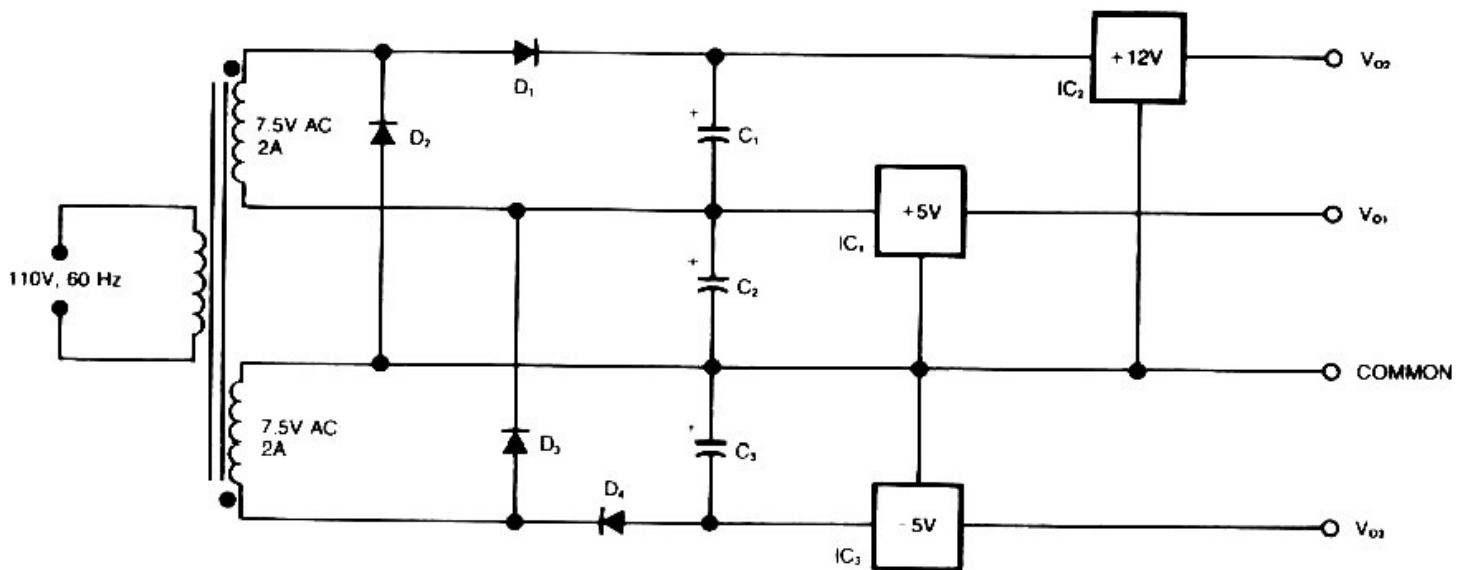
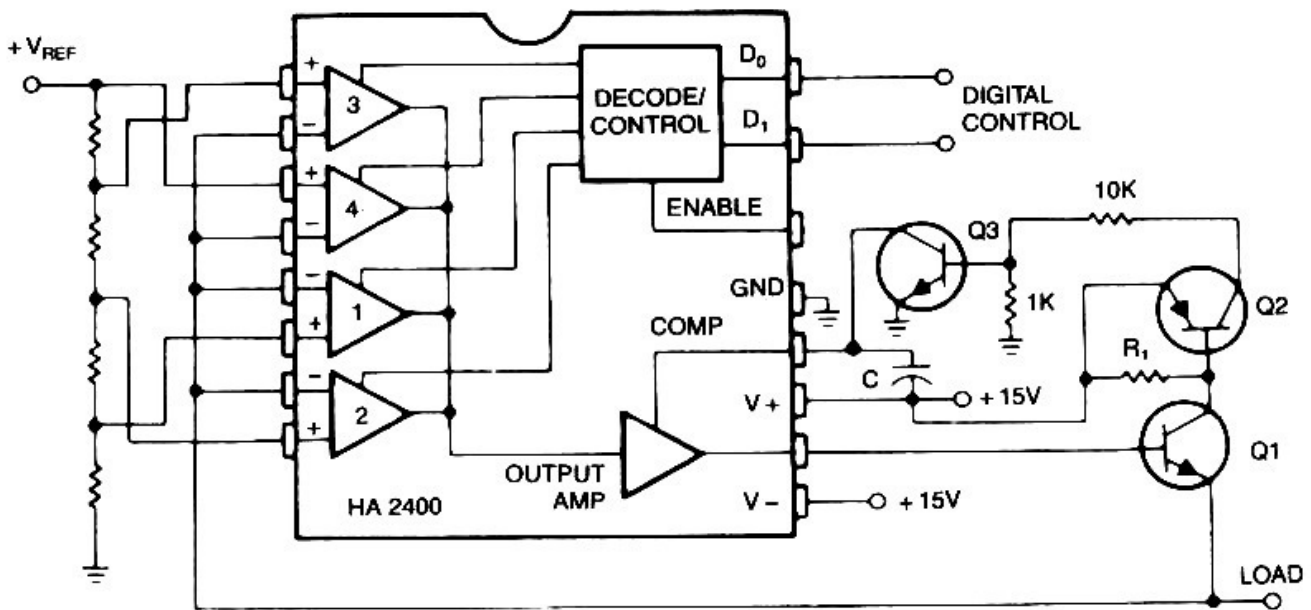


Fig. 2-22

THREE-RAIL POWER SUPPLY (cont.)

This circuit generates three supply voltages using a minimum of components. Diodes D2 and D3 perform full-wave rectification, alternately charging capacitor C2 on both halves of the ac cycle. On the other hand, diode D1 with capacitor C1, and diode D4 with capacitor C3 each perform half-wave rectification. The full- and half-wave rectification arrangement is satisfactory for modest supply currents drawn from -5 and $+12$ -V regulators IC3 and IC2. You can use this circuit as an auxiliary supply in an up-based instrument, for example, and avoid the less attractive alternatives of buying a custom-wound transformer, building a more complex supply, or using a secondary winding, say 18 Vac, and wasting power in the 5-V regulators.

PROGRAMMABLE POWER SUPPLY

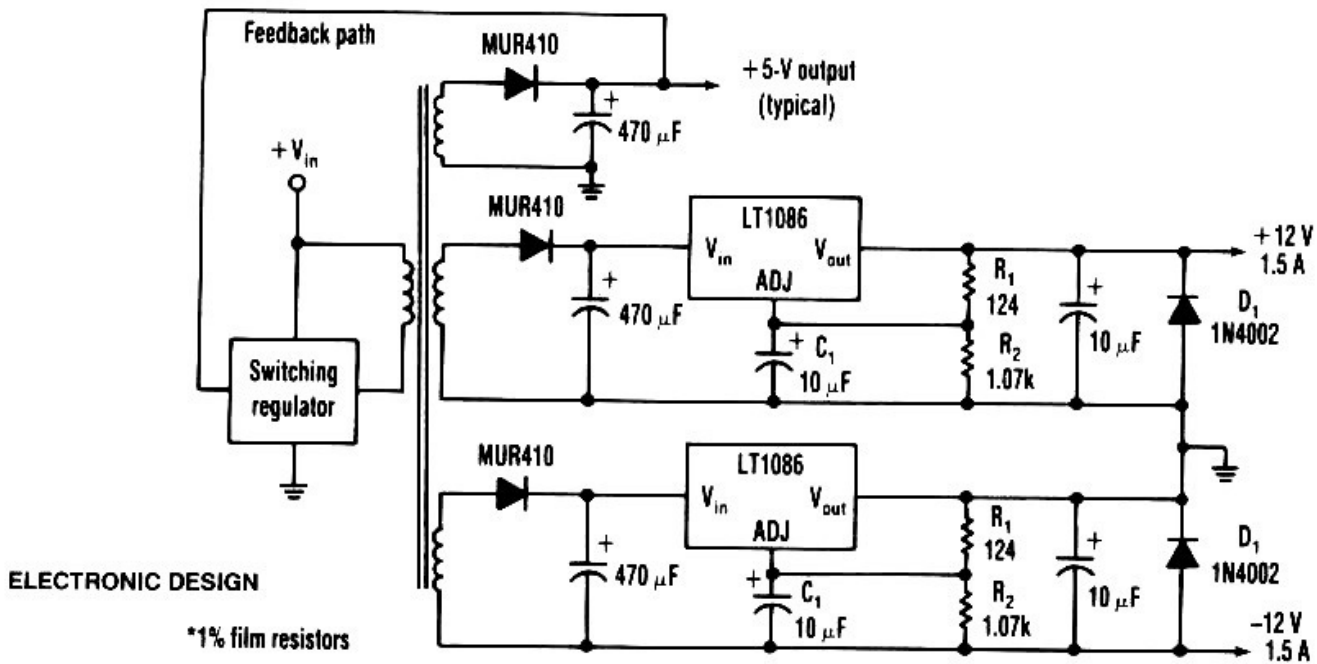


HARRIS

Fig. 2-23

Many systems require one or more relatively low-current voltage sources which can be programmed to a few predetermined levels. The circuit shown above produces positive output levels, but could be modified for negative or bipolar outputs. Q1 is the series regulator transistor, selected for the required current and power capability. R1, Q2, and Q3 form an optional short circuit protection circuit, with R1 chosen to drop about 0.7 V at the maximum output current. The compensation capacitor, C, should be chosen to keep the overshoot, when switching, to an acceptable level.

EFFICIENT NEGATIVE VOLTAGE REGULATOR

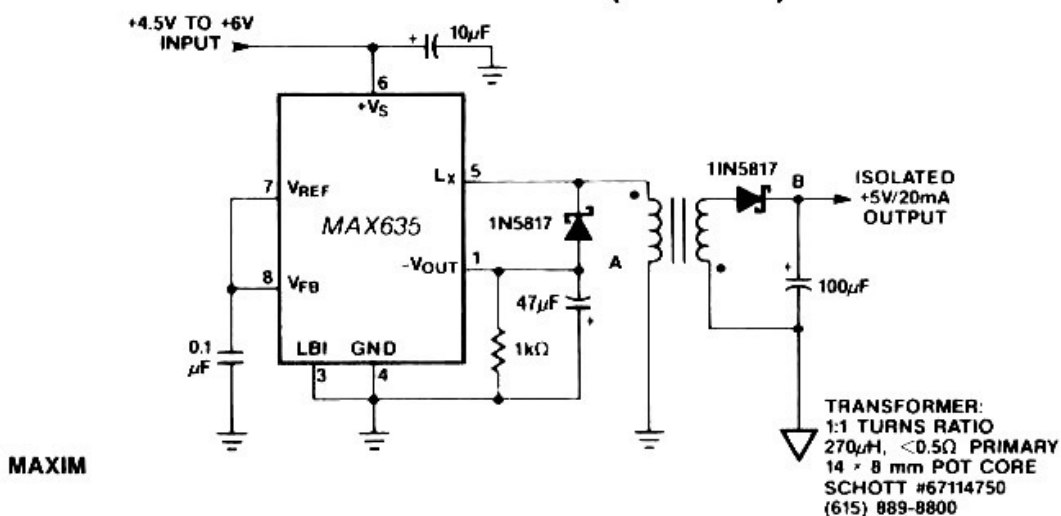


One way to provide good negative-voltage regulation is with a low-dropout positive-voltage regulator operating from a well-isolated secondary winding of a switch-mode circuit transformer. The technique works with any positive-voltage regulator, although highest efficiency occurs with low-dropout types.

Under all loading conditions, the minimum voltage difference between the regulator V_{IN} and V_{OUT} pins must be at least 1.5 V, the LT1086's low-dropout voltage. If this requirement isn't met, the output falls out of regulation. Two programming resistors, R_1 and R_2 , set the output voltage to 12 V, and the LT1086's servo the voltage between the output and its adjusting (ADJ) terminals to 1.25 V. Capacitor C_1 improves ripple rejection, and protection diode D_1 eliminates common-load problems.

Since a secondary winding is galvanically isolated, a regulator's 12 V output can be referenced to ground. Therefore, in the case of a negative-voltage output, the positive-voltage terminal of the regulator connects to ground, and the -12 V output comes off the anode of D_1 . The V_{IN} terminal floats at 1.5 V or more above ground.

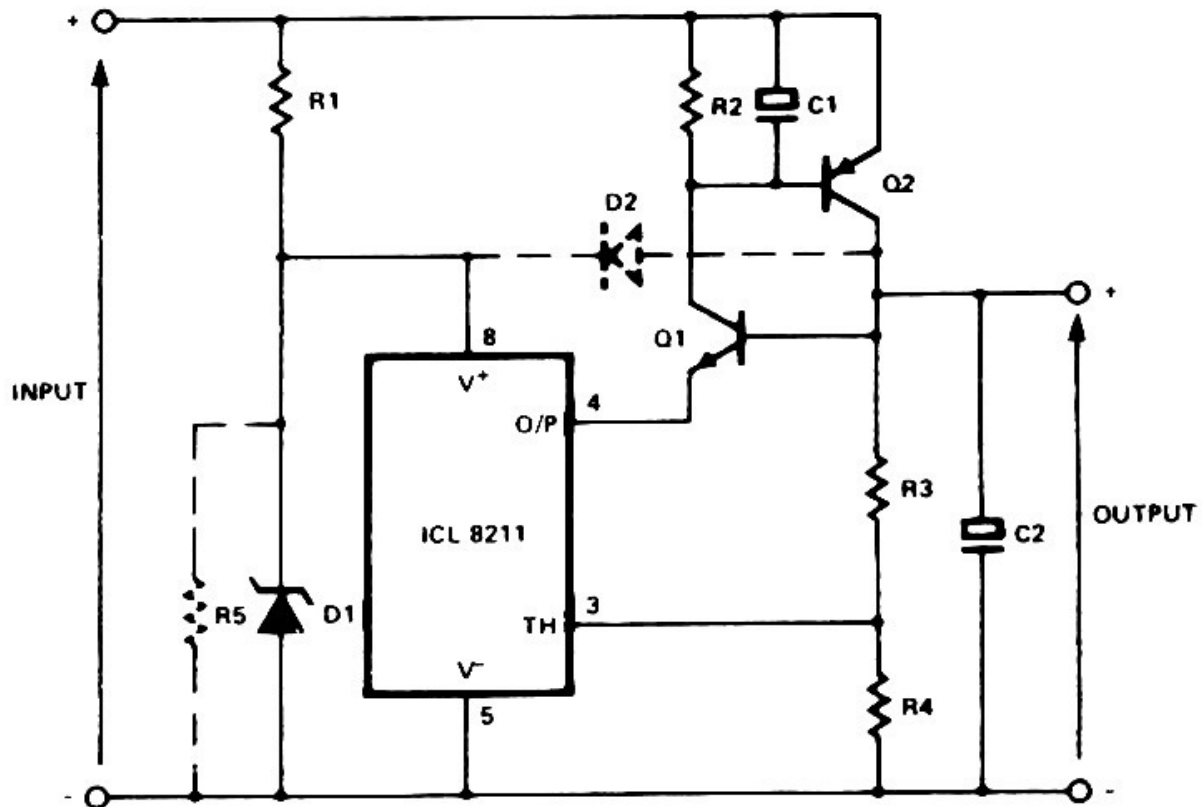
5 V-TO-ISOLATED 5 V (AT 20 mA) CONVERTER



5 V-TO-ISOLATED 5 V (AT 20 mA) CONVERTER (cont.)

In this circuit, a negative output voltage dc-dc converter generates a -5-V output at pin A. In order to generate -5 V at point A, the primary of the transformer must fly back to a diode drop more negative than -5 V . If the transformer has a tightly coupled 1:1 turns ratio, there will be a 5 V plus a diode drop across the secondary. The 1N5817 rectifies this secondary voltage to generate an isolated 5-V output. The isolated output is not fully regulated since only the -5 V at point A is sensed by the MAX635.

POSITIVE REGULATOR WITH npn AND pnp BOOST

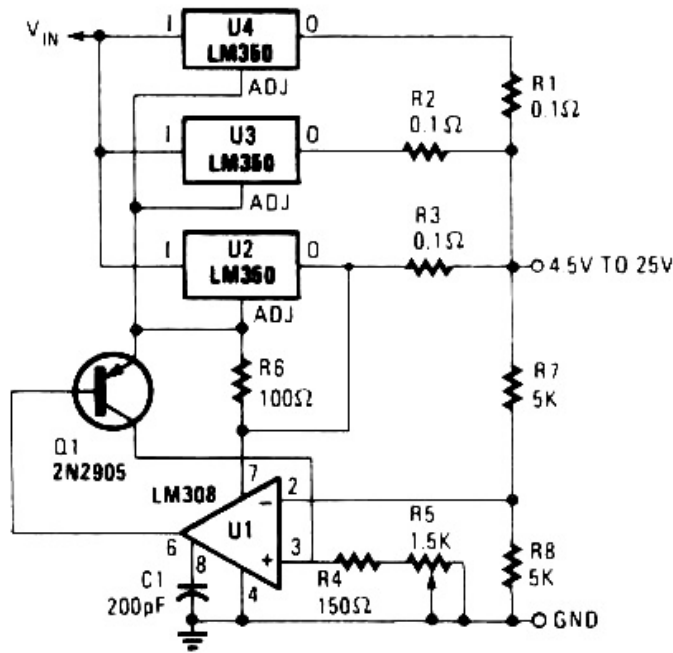


INTERSIL

Fig. 2-26

In the circuit, Q1 and Q2 are connected in the classic SCR or thyristor configuration. Where higher input voltages or minimum component count are required, the circuit for thyristor boost can be used. The thyristor is running in a linear mode with its cathode as the control terminal and its gate as the output terminal. This is known as the remote base configuration.

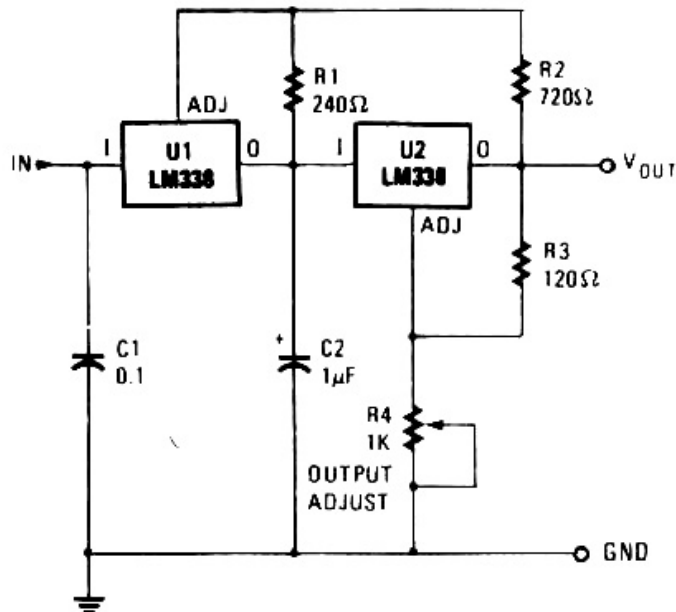
TRACKING PREREGULATOR



POPULAR ELECTRONICS

Fig. 2-27

ADJUSTABLE 10-A REGULATOR



POPULAR ELECTRONICS

Fig. 2-28

LOW-COST LOW-DROPOUT LINEAR REGULATOR

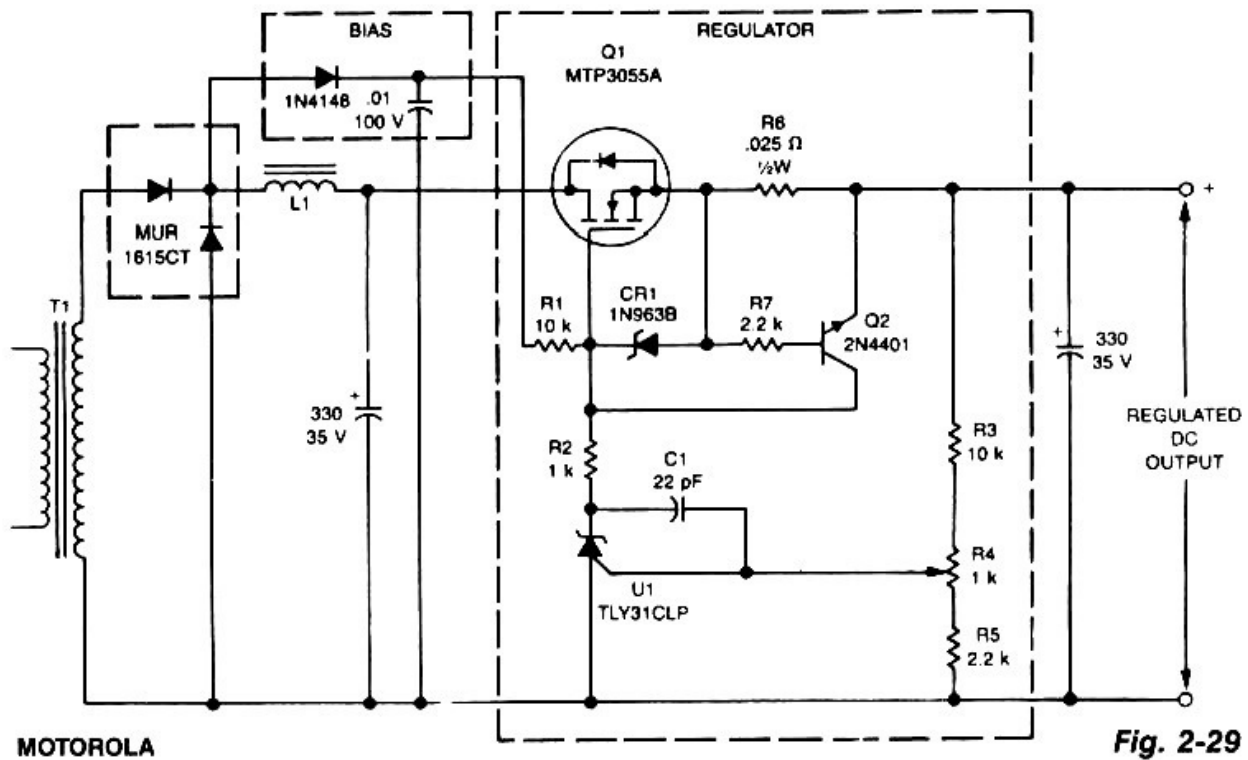


Fig. 2-29

This linear post regulator provides 12 V at 3 A. It employs TL431 reference U1 which, without additional amplification, drives T MOS MTP3055A gate Q1 series pass regulator. Bias voltage is applied through R1 to Q1's gate, which is protected against overvoltage by diode CR1. Frequency compensation for closed-loop stability is provided by C1.

Key performance features are:

Dropout voltage:	0.6 V	Load regulation:	10 mV
Line regulation:	± 5 mV	Output ripple:	10 mV pk-pk

VOLTAGE DOUBLER

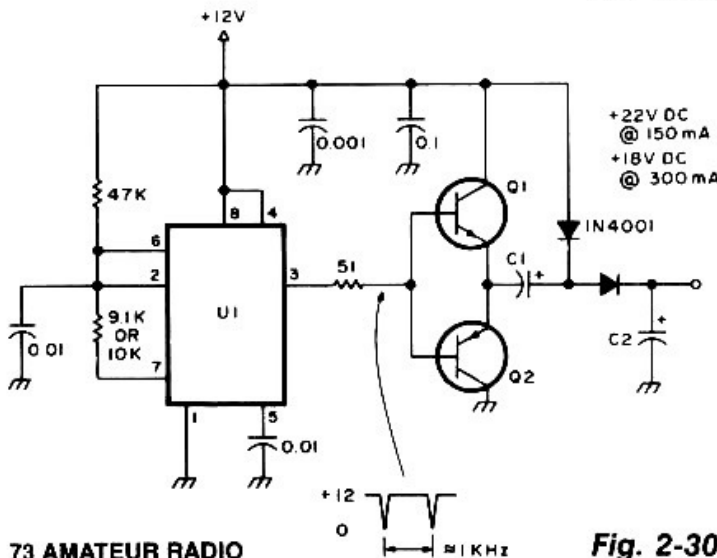
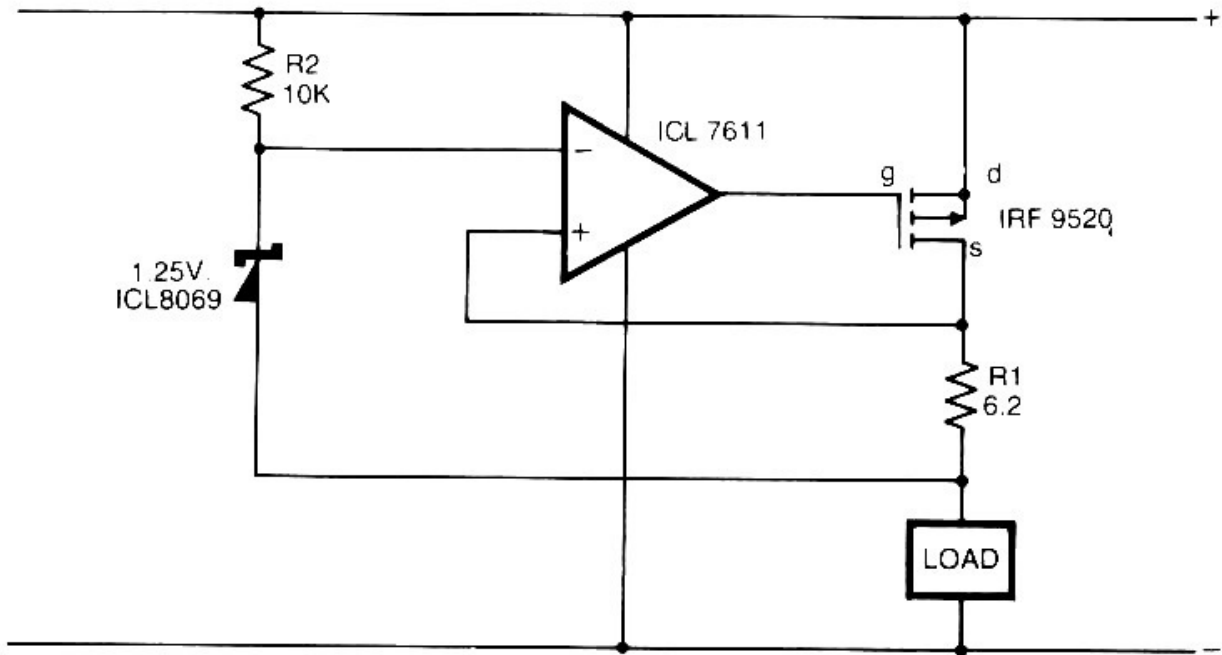


Fig. 2-30

This circuit drives relays of 24 and 18 Vdc from a 12-V power supply. Use this circuit with almost any pnp or npn power transistor.

Parts: U1: NE 555 timer. C1 and C2: 50 μ F/25 Vdc. Q1: TIP29, TIP120, 2N4922, TIP61, TIP110, or 2N4921. Q2: TIP30, TIP125, 2N4919, TIP62, TIP115, or 2N4918.

SAFE CONSTANT-CURRENT SOURCE

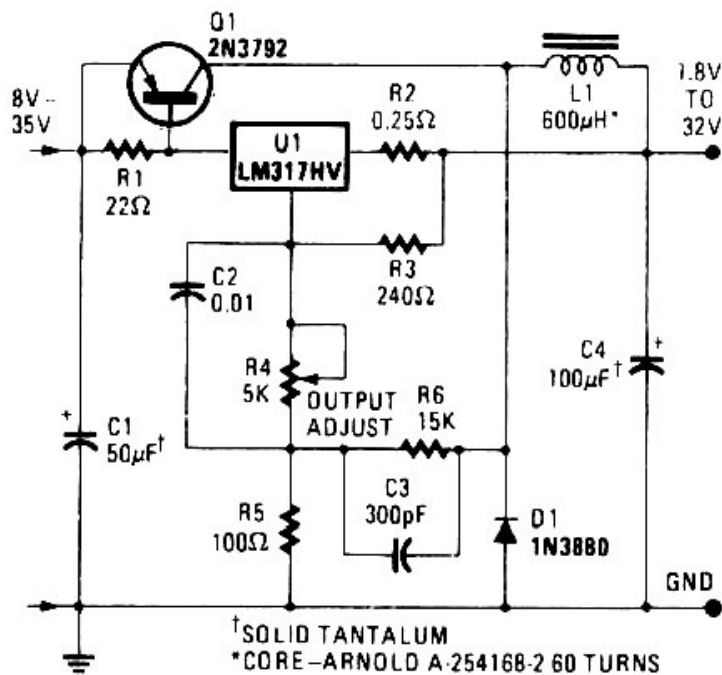


ELECTRONIC ENGINEERING

Fig. 2-31

In the circuit shown, a CMOS op amp controls the current through a p-channel HEXFET power transistor to maintain a constant voltage across R1. The current is given by: $I = V_{REF}/R_1$. The advantages of this configuration are: (a) in the event of a component failure, the load current is limited by R1; and (b) the overhead voltage needed by the op amp and the HEXFET is extremely low.

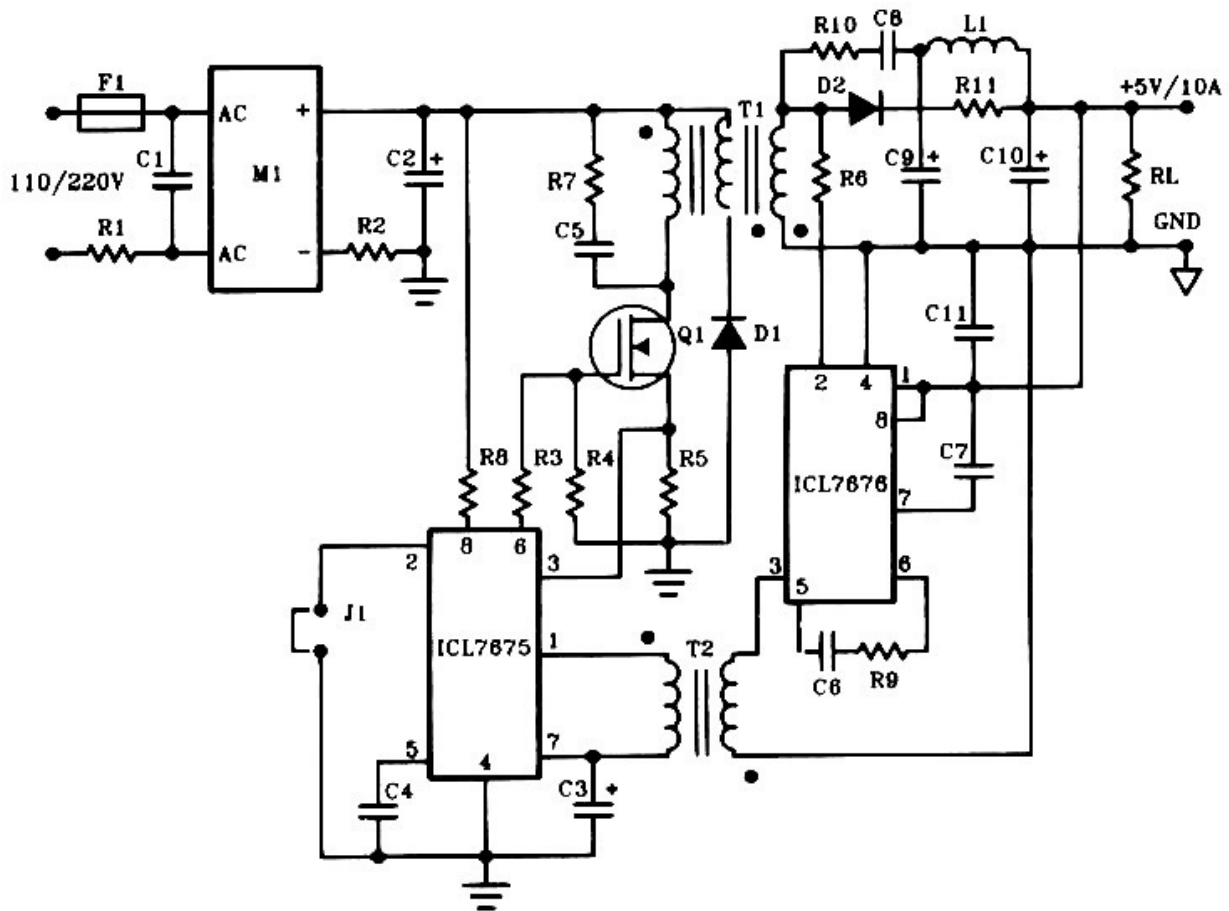
LOW-COST 3-A SWITCHING REGULATOR



POPULAR ELECTRONICS

Fig. 2-32

50-W OFF-LINE SWITCHING POWER SUPPLY



Component Values Table

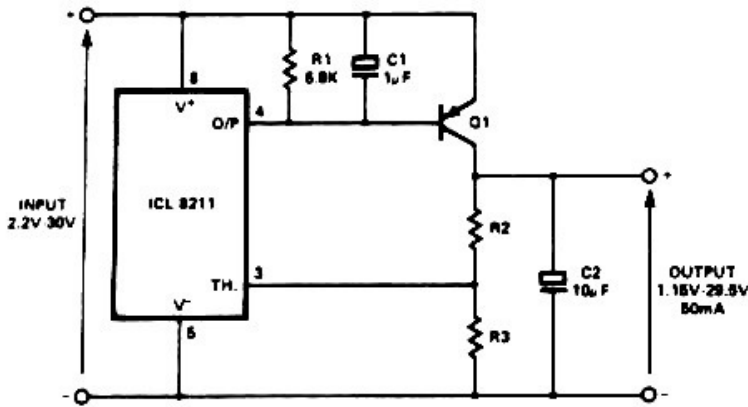
C1	0.022 μ F/400V	R1	100 Ω at 25 $^{\circ}$ C	L1	25 μ H
C2	470 μ F/250V	R2	1 Ω /1W	D1	1N4937
C3	470 μ F/16V	R3	10 Ω /0.25W	D2	MBR1035
C4	220 pF/100V	R4	100 k Ω /0.25W	T1	Lp = 9 mH, n = 1:15
C5	470 pF/500V	R5	0.33 Ω /1W	T2	50 μ H, n = 1:3
C6	2200 pF/500V	R6	10 k Ω /0.25W	F1	Fuse 1 A/SB
C7	270 pF/500V	R7	390 Ω /2W	M1	Diode Bridge
C8	39 pF/500V	R8	22 k Ω /10W	Q1	BUZ80A/IXTP4N80 (220VAC)
C9	11,000 μ F/6.3V	R9	68 Ω /0.25W	Q1	GE IRF823 (110VAC)
C10	10 μ F/16V	R10	10 Ω /0.5W		
C11	0.047 μ F/10V	R11	3.3 Ω /0.5W		
		RL	5 Ω /10W		

INTERSIL

Fig. 2-33

The schematic shows a 50-W power supply with a 5-V 10-A output. It is a flyback converter operating in the continuous mode. The circuit features a primary side and secondary side controller with full-protection from fault conditions such as overcurrent. After the fault condition has been removed, the power supply will enter the soft-start cycle before recommencing normal operation.

POSITIVE REGULATOR WITH pnp BOOST



INTERSIL

Fig. 2-34

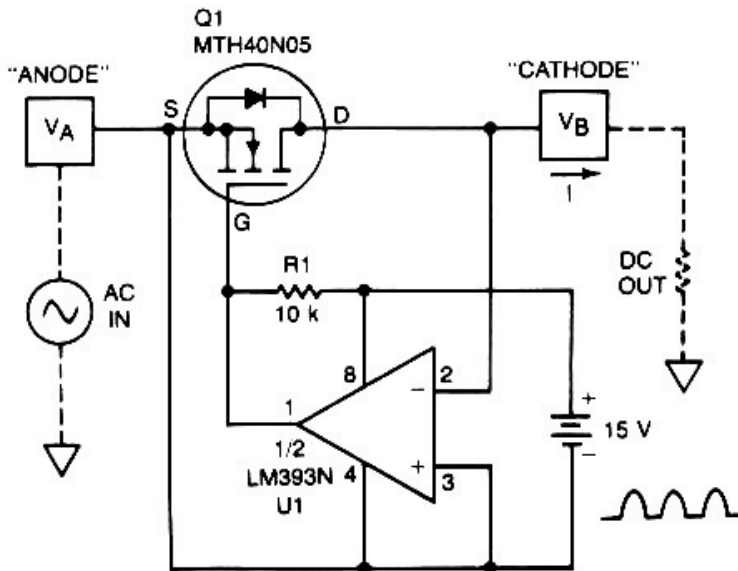
The IC8211 provides the voltage reference and regulator amplifier, while Q1 is the series pass transistor. R1 defines the output current of the IC8211, while C1 and C2 provide loop stability and also act to suppress feedthrough of input transients to the

output supply. R2 and R3 determine the output voltage as follows:

$$V_{OUT} = 1.5 \times \frac{R_2 + R_3}{R_3}$$

In addition, the values of R2 and R3 are chosen to provide a small amount of standing current in Q1, which gives additional stability margin to the circuit. Where accurate setting of the output voltage is required, either R2 or R3 can be made adjustable. If R2 is made adjustable, the output voltage will vary linearly with the shaft angle; however, if the potentiometer wiper was to open the circuit, the output voltage would rise. In general, therefore, it is better to make R3 adjustable, since this gives fail-safe operation.

LOW FORWARD-DROP RECTIFIER CIRCUIT



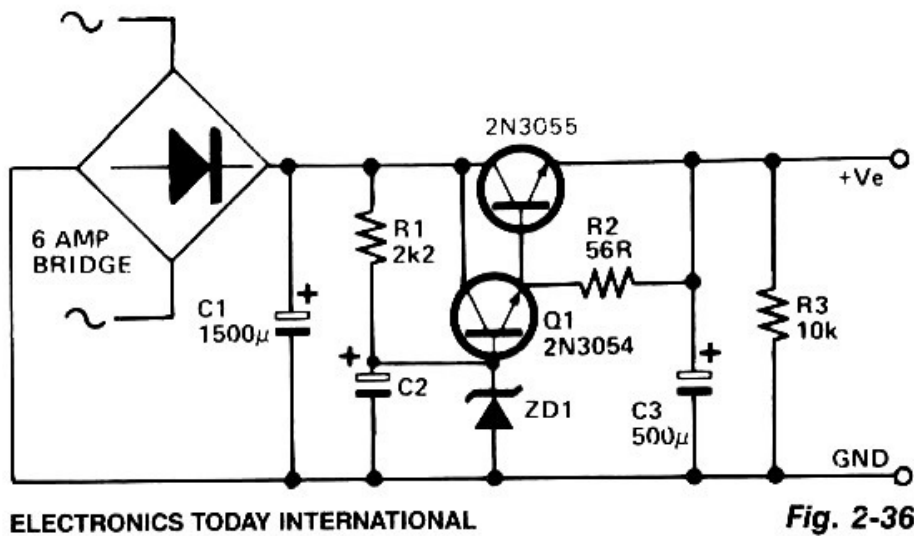
MOTOROLA

Fig. 2-35

A CMOS power FET, Q1, and an LM393 comparator provide a high-efficiency rectifier circuit. When V_A exceeds V_B , U1's output becomes high and Q1 conducts. Conversely, when V_B exceeds V_A , the comparator output becomes low and Q1 does not conduct.

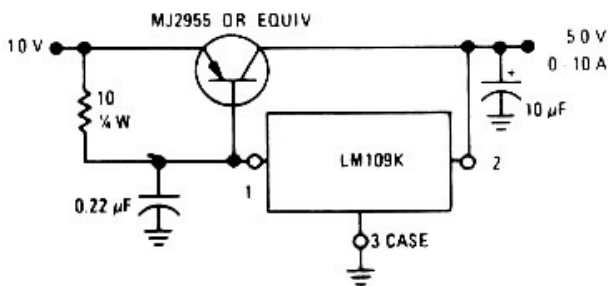
The forward drop is determined by Q1's on resistance and current I . The MTH40N05 has an ON resistance of 0.028Ω ; for $I = 10 \text{ A}$, the forward drop is less than 0.3 V . Typically, the best Schottky diodes do not even begin conducting below a few hundred mV.

LOW-RIPPLE POWER SUPPLY



This circuit can be used where a high current is required with a low-ripple voltage (such as in a high-powered class AB amplifier when high-quality reproduction is necessary). Q1, Q2, and R2 can be regarded as a power-Darlington transistor. ZD1 and R1 provide a reference voltage at the base of Q1. ZD1 should be chosen thus: $ZD_1 = V_{out} - 1.2$. C2 can be chosen for the degree of smoothness as its value is effectively multiplied by the combined gains of Q1/Q2, if 100 μ F is chosen for C2, assuming minimum hfe for Q1 and Q2, $C = 100 \times 15(Q1) \times 25(Q2) = 37,000 \mu$ F.

5.0-V/10-A REGULATOR



5.0-V/3.0-A REGULATOR

